The Middle Triassic Megafossil Flora of the Basin Creek Formation, Nymboida Coal Measures, New South Wales, Australia. Part 6. Ginkgophyta

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The Ginkgophyte Flora from two quarries in the Basin Creek Formation of the Middle Triassic Nymboida Coal Measures of north eastern NSW Australia is described and illustrated. This includes the first record from Australia of *Hamshawvia,* a female strobilus bearing a pair of megasporophylls. *Hamshawvia* and the male strobilus *Stachyopitys* are regarded as the fructifications of the plants bearing *Sphenobaiera* leaves. Two of the *Hamshawvia* specimens are placed in *H. distichos* sp. nov. and a third in *H.* sp. A. Several specimens of *Stachyopitys* strobili are compared with *S. matatilongus* and *S. lacrisporangia* from the Molteno Formation of South Africa. The Ginkgophyte leaves form c. 10% of the collected leaf fossils from the Nymboida localities and are placed in the genera *Ginkgoites* (four morpho-species) and *Sphenobaiera* (eight morpho-species). In the absence of preserved cuticle the morpho-species are differentiated on characters of gross morphology. In five cases where sufficient specimens of a particular form are available to indicate a natural range of variation they are placed in a 'morpho-species complex'. New leaf taxa are the morpho-species *Ginkgoites nymboidensis* sp. nov., *Sphenobaiera paucinerva* sp. nov., *S. densinerva* sp. nov. and *S. nymbolinea* sp. nov.

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KEYWORDS: *Ginkgoites*, Ginkgophyta, *Hamshawvia,* Nymboida Coal Measures, *Sphenobaiera* fructifications, *Stachyopitys,* Triassic Flora.

INTRODUCTION

In this sixth part of the series describing the early Middle Triassic Nymboida Flora, leaves assigned to the Ginkgophyte genera *Ginkgoites* and *Sphenobaiera* and the affiliated fertile organs *Stachyopitys* and *Hamshawvia* are illustrated and described. This is the first description of the female Ginkgophyte megasporophyll *Hamshawvia* from Australia.

Part 1 (Holmes 2000) of this series dealt with the Bryophyta and Sphenophyta; Part 2 (Holmes 2001) with the Filicophyta; Part 3 (Holmes 2003) with fern-like foliage; Part 4 (Holmes and Anderson 2005a) with the genus *Dicroidium* and its fertile organs *Pteruchus* and *Umkomasia*; Part 5 (Holmes and Anderson 2005b) with the genus *Lepidopteris* and its affiliated fructifications *Peltaspermum* and *Antevsia*, and the genera *Kurtziana*, *Rochipteris* and *Walkomiopteris*.

GINKGOPHYTA – A SHRINKING LINEAGE.

The Ginkgophytes have a long evolutionary history ranging from the Carboniferous to the present (Taylor and Taylor 1993; Holmes 1996). However some early species are known only as isolated specimens and their affinities are questionable (Taylor and Taylor 1993; Rothwell and Holt 1997). From the Late Palaeozoic to the early Tertiary the Ginkgophyta had an almost global distribution with a peak of diversity in the late Mesozoic and early Tertiary (Zhou 1997; Rothwell and Holt 1997). The last recorded occurrences in Gondwana are from the Eocene of Argentina (Berry 1938) and the Palaeogene of Tasmania (Hill and Carpenter 1999). It has been suggested that the fleshy *Ginkgo* fruits were ingested by herbivore dinosaurs that acted as dispersal agents for the seeds. The extinction of the dinosaurs at the end of the Cretaceous may have resulted in the contraction in both range and diversity throughout the Tertiary that brought *Ginkgo* to the brink of extinction (Tralau 1968). Today the last single extant representative is *Ginkgo biloba* which may no longer exist in the wild (Li 1956) but is now cultivated almost world-wide.

Previous Gondwana Triassic records of Ginkgophyta include: from Australia – Tenison Woods (1883), Ratte (1887, 1888), Johnston (1888), Shirley (1887, 1898), Dun (1909), Walkom (1917, 1924, 1928), Retallack (1977), Retallack et al. (1977), Holmes (1982, 1996); from South Africa – Seward (1903, 1908), DuToit (1927, 1932), Baldoni (1980), Anderson and Anderson (1983, 1985, 1989, 2003); from South America – Frenguelli (1946), Menendez (1951), Artabe (1985), Azcuy and Baldoni (1990), Gnaedinger and Herbst (1999); from Malagasy – Carpentier (1935) and from India – Pal (1984).

METHODS

The material described in this paper is based mainly on collections made by the senior author and his family from two Nymboida quarries over a period of forty years and on limited material held in the fossil collections of the Australian Museum, Sydney, and also those in the Geology Department of the University of New England, Armidale, as noted in Retallack (1977) and Retallack et al. (1977). The Nymboida material was collected mostly from blocks fallen from the working quarry faces so the exact horizon or source of most specimens is uncertain.

Details of the Coal Mine Quarry and Reserve Quarry together with a summary of the geology of the Basin Creek Formation, the Nymboida Coal Measures and the Nymboida Sub-Basin were provided in Holmes (2000). An earlier study by McElroy (1962) of the Clarence-Moreton Basin included the older geological units now regarded as formations within the Nymboida Sub-Basin.

In the Holmes Nymboida collection, leaves attributed to the Ginkgophyta comprise c. 10% of the c. 2600 catalogued specimens with *Ginkgoites* forming c. 2.5% and *Sphenobaiera* c. 7.5%. This contrasts with that of the Benolong Flora in the Napperby Formation near Dubbo, Australia, (Holmes 1982) where *Sphenobaiera* leaves are the most numerous of the preserved plant remains. In their collections of fossil plants from the Molteno Formation of South Africa, Anderson and Anderson (1989) noted that leaves of *Sphenobaiera* were the second most common taxon with a mean abundance of 30% in 32 assemblages. Fertile organs attributed to the Ginkgophyta are extremely rare in the fossil record.

Leaves from a single plant of the extant *Ginkgo biloba* may exhibit a great amount of variation which points to the probability of a similar range of variation in fossil Ginkgophyte leaves (Walkom 1917). Thus the identification to species level of Ginkgophyte leaves from large assemblages with a wide range of variation and intergrading forms raises problems similar to those experienced with the *Dicroidium* genus (Holmes and Anderson 2005a) and the *Lepidopteris* and *Kurtziana* genera (Holmes and Anderson 2005b). Anderson and Anderson (1989) noted that at their Molteno localities Mat111 and Bir111 three morphotaxa of *Sphenobaiera* formed a complex and intergrading series. Harris et al. (1974) also recognised that leaves of the Ginkgoales in the Yorkshire Flora varied greatly in form and that specific distinction was difficult. They suggested that differences within a local assemblage and between assemblages could arise from a slight peculiarity of genetic balance between populations of trees or by the environment. Zhou (1997) also noted that almost all species that have been studied in some detail exhibit a rather wide spectrum of leaf variation. The fossil plants at Nymboida come from a range of facies that represent different environments so it is probable that some of the variation within the Nymboida leaf complexes may have been influenced by environmental conditions.

Harris (1935) believed that cuticular details were essential for specific determination of *Ginkgoites*. Anderson and Anderson (1989) noted that their *Sphenobaiera* and *Ginkgo* (= *Ginkgoites*) cuticles appeared to share a more or less equal number of features in the epidermal structure and also with those of the genera *Lepidopteris* and *Dejerseya*. At the Nymboida localities all cuticle has been destroyed in a heating event during the Cretaceous (Russel 1994).

Due to the absence of cuticle in any of our otherwise well-preserved plant material the identification of leaves is based on features of gross morphology; e.g. size and form of lamina; angle of divergence of the lamina from the base; form of the petiole; nature of the segmentation and vein density in distal portions of the lamina. In cases where numerous specimens of a somewhat similar form are available this variation is encompassed in our identification of the group as a 'morpho-species complex'. Leaves with a fan-shaped lamina (flabbelate) and a distinct petiole are placed in *Ginkgoites*. Wedge-shaped leaves (cuneate) contracting to a petiolate-like base are placed in *Sphenobaiera*. This differentiation is partly subjective and certain leaves could equally well be placed in *Ginkgoites* or *Sphenobaiera*.

Based on the presence of associated or attached fertile material in their large Molteno Formation collections, Anderson and Anderson (2003) have placed *Ginkgoites* and *Sphenobaiera* leaves in separate Families and Classes. In the absence of any leaves attached to fertile organs at Nymboida we have not placed our morpho-taxa above generic rank.

The Ginkgophytes were widespread in the Northern Hemisphere during the early Mesozoic and some northern morpho-taxa are closely similar in gross morphology to individuals in the Nymboida flora. However, due to problems relating to time and geographic separation we have made comparisons only with Gondwana material.

The flabellate leaves of the *Rochipteris* genus (Gnaedinger and Herbst 1998, Baronne-Nugent et al. 2003, Holmes and Anderson 2005b) and the leaves associated with *Kannaskoppia* (Anderson and Anderson 2003) may be confused with the ginkgophytes. They are differentiated by the usually asymmetrical dissection of the lamina, the more delicate venation with anastomoses and by their distinct stomata.

The types and all illustrated material in this paper have been allocated AMF numbers and are housed in the Palaeontology Department of the Australian Museum, Sydney.

SYSTEMATIC PALAEOBOTANY

Order Ginkgophyta

Genus *Ginkgoites* Seward 1919

Ginkgoites nymboidensis Holmes and Anderson sp. nov.

Figures 1 A,B; 2 A,B.

Diagnosis

Leaf lamina semicircular, elegantly dissected almost to base into six primary elongated narrow-elliptic to spathulate segments, each segment again deeply to shallowly incised, apices rounded.

Description

A medium-sized *Ginkgoites* leaf with elegant semicircular leaves, 75–100 mm long, 90–140 mm wide; basal angle 180°–200°; petiole slender, 3mm wide, length unknown; lamina symmetrically dissected almost to the base into six primary segments; each segment again incised from ¼ to ¾ to the base; ultimate lobes parallel-sided or elongate-spathulate, 6–12 mm in width, the inner segments longer than the outside segments; apices rounded-obtuse or rarely shallowly notched; veins forking in proximal portion of primary segments then running straight and parallel to the apical margin; vein density in the distal region of the segments 12–14/10 mm.

Holotype

AMF129928. Australian Museum, Sydney.

Type locality

Coal Mine Quarry, Nymboida. Basin Creek Formation, Nymboida Coal Measures, early Middle Triassic.

Other material

AMF129926–7, AMF130170, Coal Mine Quarry; AMF129929, Reserve Quarry.

Discussion

This uncommon morpho-taxon bears some features with the leaf illustrated by Tenison-Woods (1883, pl. 4, fig. 3) as *Jeanpaulia bidens*. While that specimen is somewhat similar in dissection pattern and shape of the lobes and general proportions it is smaller and too poorly preserved to make meaningful comparisons. The leaves identified by Shirley (1897, pl. 6, figs 1,2; 1898, pl.19, fig. 1, pl. 21) as *Baiera* (*Jeanpaulia*) *bidens* and by Walkom (1917, pl. 3, fig. 1) as *Baiera bidens*, differ from Tenison–Woods specimen by the lamina being incised to the base into linear segments, each of which is again incised almost to the base to form elongated narrow elliptic segments with acute apices. Walkom's specimen was selected as the type for *Ginkgo denmarkensis* by Anderson and Anderson (1989). *Ginkgoites waldeckensis* (Anderson and Anderson 1989), Gnaedinger and Herbst (1999) and *Ginkgoites koningensis* Anderson and Anderson (1989, 2003) are closely similar in lamina shape to *Ginkgoites nymboidensis* but differ by their much denser venation. *G. matatiensis* Anderson and Anderson (1989) differs by the four secondary segments on either side of the median cleft. *G. semirotunda* Holmes (1982) is smaller and with a slightly different dissection of the lamina. *Ginkgo palmata* (Ratte) Anderson and Anderson

1989, which includes *G. simmondsii* Shirley (1898) and *Baiera simmondsii* (Shirley) Walkom 1917, differs from *Ginkgoites nymboidensis* by the greater number of primary segments and denser venation. *G. nymboidensis* is similar to some forms of *G. denmarkensis* (Fig. 3B) but differs by its semi-circular lamina and elegant partially dissected segments.

'*Ginkgoites denmarkensis* Anderson and Anderson 2003 complex'

Figures 3A,B; 4A; 5A,B; 6A; 7A; 8A.

Holotype

University of Queensland F1411, Denmark Hill, Ipswich Coal Measures, Queensland.

Selected references

1917 *Baiera bidens*, Walkom, pl. 3, fig. (2).
1965 *Ginkgo digitata*, Hill et al. pl. T9, fig. 6.
1965 *Ginkgoites simmondsii*, Hill et al., pl. T XI, fig. 3.
1965 *Ginkgoites ginkgoides*, Hill et al., pl. T XI, fig.5.
1989 *Ginkgo denmarkensis*, Anderson and Anderson p.227, t. fig. 2, pl. 322.
1999 ?*Ginkgoites* sp., Gnaedinger and Herbst, p. 285, figs 4B, 5D-F.
2003 *Ginkgoites denmarkensis*, Anderson and Anderson, p.197, t. fig. 3.

Description

Medium to large flabbelate leaves with a long slender to strong petiole to 40 mm long, 2–4 mm wide; lamina 100–170 mm long, 100–200 mm wide; basal angle 140°–270°; divided into six primary segments that range in form from those divided from ¼ from apex to almost to the base to form elongated almost linear or narrow spathulate segments that taper distally to acute or rounded apices (Figs 3A,B, 4A), to other forms where the primary segments become broad-elliptical with entire, notched or shallowly incised apices (Figs 5A,B, 6, 7, 8A). Veins fork near the base then run straight and parallel to the apex of the lobes; density in the distal portion 12–14/10 mm and in rare specimens to 16–18/10 mm.

Material

AMF129930–4, 129936–7, Coal Mine Quarry; AMF129935, Reserve Quarry.

Discussion

Leaves in the '*G. denmarkensis* complex' are common and variable. Some leaves from Nymboida (Fig. 3A) are closely similar to the type specimen of *G. denmarkensis* selected by Anderson and Anderson (1989 p. 227) in which each of the six primary lobes is dissected halfway or more to the base to form elongated parallel-sided to slightly expanding secondary lobes contracting distally to an acute apex. Some forms e.g. Fig. 3B are close to *G. nymboidensis* but are less elegantly symmetrical and with deeper incisions of the secondary lobes. The very large leaf (Fig. 4A) is close in form to the Molteno leaf *G. aviamnica* that differs by the less dense venation (6/10 mm). Forms with less deep incisions and broadening of the primary lobes (Figs 5A,B, 6A, 7A, 8A) that we have included in this complex are close to the Molteno *G. matatiensis* which differs by the dissection into eight primary segments. The fragmentary leaves figured by Gnaedinger and Herbst (1999, figs 4b, 5D–F) as *Ginkgoites* sp. from the Tranquilo Group of Patagonia are closely similar in outline and venation to *G. denmarkensis*.

Ginkgoites ginkgoides (Shirley 1898) Florin 1936.

Figures 9A,B

Type specimen

F104c Queensland Geological Survey, Denmark Hill, Ipswich Coal Measures, Queensland.

Selected references

1898 *Baiera ginkgoides* Shirley, p. 13, pl. 3, fig. 1.
1917 *Baiera ginkgoides* Walkom, p. 12, pl. 3, figs 3,4.

Description

Medium-sized incomplete *Ginkgoites* leaves divided into four to six widely separated primary segments attenuated basally, expanding distally; apices not known; petioles stout, to 6 mm wide, length not known; veins prominent, density c. 10–12/10 mm.

Material

AMF129941–2, Coal Mine Quarry.

Discussion

These rare specimens have close similarities with those illustrated by Shirley (1898) and Walkom (1917). At Nymboida they occur in allocthonous deposits of mostly macerated plant fragments. These specimens are probably decorticated or decaying leaves and could possibly have been derived from *G. denmarkensis* trees.

***Ginkgoites* sp. cf *G. waldeckensis* (Anderson and Anderson 1989) Gnaedinger and Herbst 1999**
Figures 8B–D.

Description

Small *Ginkgoites* leaves, lamina semicircular to flabbelate, 25–35 mm long, 35–45 mm wide; petiole 10 mm long, 1–1.5 mm wide with an expanded leafbase: lamina diverging from base at an angle of 130°–180°, deeply incised to form six major segments, each segment again less deeply incised to form 12 terminal lobes with truncate or shallowly notched apices; each lobe has from four to six veins giving a vein density in apical portions of c. 16–24/10 mm.

Material

AMF129938, 129940, Coal Mine Quarry; AMF129939, Reserve Quarry.

Discussion

The rare semi-circular, deeply segmented leaves of this morpho-species differ from any previously figured species from Australia. The few Nymboida specimens are similar in lamina size and outline to some forms of the variable *Ginkgoites waldeckensis* from the Moltenon Formation of South Africa (Anderson and Anderson 1989) but the long slender petioles have not been observed. The leaves from the El Tranquilo Group of Patagonia placed by Gnaedinger and Herbst (1999) in *G. waldeckensis* are larger in size and divided four or five times into narrow linear segments with finer venation.

Genus *Sphenobaiera* Florin 1936

'*Sphenobaiera stormbergensis* (Seward 1903) Frenguelli 1948 complex'
Figures 10A; 11A,B; 12A,B; 13A

Holotype

Baiera stormbergensis Seward 1903, F11670 South African Museum

Selected references

1903 *Baiera stormbergensis* Seward fig.8(3).
1924 *Biera bidens* Walkom pl.21, fig.2.
1989 *Sphenobaiera stormbergensis* Anderson and Anderson p.146, pl.91, pl.100, figs 9, 18.
1999 *Sphenobaiera stormbergensis* Gnaedinger and Herbst fig.11 D,E.

Description

A medium-sized *Sphenobaiera* with wedge-shaped leaves contracted basally into a stout petiole to 6 mm wide and 50–60 mm long; angle of divergence from 50°–80°; lamina from 110–150 mm long and to 140 mm wide; deeply incised to form 4 to 6 major segments, each segment again shallowly incised to form up to 12 ultimate, parallel-sided segments with rounded apices; density of venation in distal portion of segments c. 10/10 mm.

Material

AMF129943 and counterpart AMF129947, AMF129953, AMF121025–6, AMF130169, all Coal Mine Quarry; AMF130168, Reserve Quarry.

Discussion

The Nymboida material assigned to this complex is relatively common. The leaves are close to *S. stormbergensis* from the Molteno Formation of South Africa but sometimes differ by the presence of a stout variously elongated petiolate base. *S. coronata* Anderson and Anderson, also from the Molteno Formation, has a similar density of venation and may be stoutly petiolate but differs by a broader divergence and more irregular incisions of the lamina. *S. stormbergensis* differs from *S. densinerva* (below) by the less dense venation. The woody interveinal striae noted by Retallack et al. (1977) in a leaf fragment referred to *S. stormbergensis* from Cloughers Creek near Nymboida, have not been observed in material from the Coal Mine and Reserve Quarries.

***Sphenobaiera paucinerva* Holmes and Anderson sp. nov.**
Figures 10B, 14A–D

Diagnosis

A small *Sphenobaiera* leaf; lamina with deep central incision, lateral segments again less deeply incised to form four parallel-sided segments with distal margins acute, rounded or shallowly cleft; density of venation in distal portion of segments 6–10/10 mm.

Description

Small wedge-shaped leaves; lamina 60–85 mm long, 45–80 mm wide, contracting basally into a stout petiole 3 mm wide, to 20 mm long. Angle of divergence of lamina from base 60°–80°. Lamina with deep medial incision; lateral pair of segments each incised to a depth of c. 1/3 from distal margin to form four equal or irregular segments with sub-parallel margins and acute to rounded, notched or shallowly incised tips. Venation coarse, bifurcating proximally and then running parallel to distal margin, density in distal portion c. 6–10/10 mm.

Holotype

AMF129954, Australian Museum, Sydney.

Type locality

Coal Mine Quarry, Nymboida. Basin Creek Formation, Nymboida Coal Measures, early Middle Triassic.

Other material

AMF129944, AMF129955–7, Coal Mine Quarry.

Name derivation

paucinerva – referring to the less dense venation than in the somewhat similar-shaped smaller forms of leaves placed in *S. densinerva* below.

Discussion

S. paucinerva is an uncommon element in the Nymboida collection. The leaves of *S. insecta* and *S. helvetica* from the Molteno Formation of South Africa (Anderson and Anderson 1989) are divided into four segments with rounded apices. However both species are significently larger than *S. paucinervia* and have preserved and described cuticles. *S. paucinervia* may be a small form of the much larger leaved *S. stormbergensis* but there are no intermediate forms in our collection.

'Spheno*baiera densinerva* Holmes and Anderson sp. nov. complex'

Figures 10C; 15A–D; 16A,B; 17A–C; 18A–D; 19A; 20A,B.

Diagnosis

A small to large petiolate cuneate leaf divided into four short primary truncate segments or with longer parallel-sided or slightly expanding segments sometimes again shallowly incised; apices truncate or broadly obtuse; venation density in distal portion of segments c. 16–24/10 mm.

Description

A very variable cuneate leaf ranging from small to large; lamina 60–130 mm long, 40–100 mm wide; diverging at 45°–80° from a well-defined slender to stout petiole 10–30 mm long, 1.5–4 mm wide. Lamina divided by deep incisions into four segments. Some larger leaves have longer segments that may be again incised to form further parallel-sided ultimate lobes (Figs 17A, 18C), others with broad less incised laminae (Fig. 20A,B). Apices of segments truncate or broadly obtuse. Veins bifurcating only in basal portion of the lamina and then running straight and parallel to the apical margin; density of veins in distal portion of the lobes from 16–24/10 mm.

Holotype

AMF129945 and counterpart AMF129949.

Type locality

Coal Mine Quarry, Nymboida. Basin Creek Formation, Nymboida Coal Measures, early Middle Triassic.

Name derivation

densinerva – referring to the more dense venation when compared with most other Nymboida ginkgophyte material.

Other material

AMF129959–68, 129971–2, Coal Mine Quarry; AMF129969, Reserve Quarry.

Discussion

Our illustrations represent what we consider to be the range of variation of the abundant leaves within this complex, from smallest to largest leaves. The smaller leaves of *S. densinerva* (Figs 15A–D) are distinguished from the less variable *S. paucinerva* (Figs 14A–D) essentially by the denser venation. The larger leaves of *S. densinerva* (Figs 18B–E) differ from *S. stormbergensis* by the more parallel strap-like segments and by the much denser venation. The distal portion of the very large leaf in Figure 17A is closely similar in form but very much larger than the incomplete specimen of *Baiera ipsviciensis* of Shirley (1898 pl.12, fig.2) and repeated in Walkom (1917 pl.4, figs1,2)

'*Sphenobaiera schenckii* (Feistmantel 1889) Florin 1936 complex'

Figures 21A–E; 22A–D; 23A–D.

Lectotype

Baiera schencki Feistmantel 1889, pl. 3, fig. 2. (see Anderson and Anderson 1989)

Selected references

1889 *Baiera Schencki* Feistmantel, pl. 3, fig 2.
1989 *Sphenobaiera schenckii* Anderson and Anderson, p. 142, pls 57, 58, 79.
2003 *Sphenobaiera schenckii* Anderson and Anderson, pp 211, 223.

Description

A small *Sphenobaiera* leaf bisected almost to the base and each segment then symmetrically twice less deeply dissected to form eight elongate, subparallel-sided or slightly expanding ultimate segments. Leaf lamina 40–100 mm long and wide, contracting basally at a convergence angle of 45°–120° to a tapering petiole 1–3 mm wide and to 25 mm long. Venation forking in proximal portion of the lamina to form 4–8 veins running parallel to apex of ultimate lobes at a density of 15–20/10 mm.

Material

AMF129958, 129973–4, 121027–30, 121041–2, 121044, Coal Mine Quarry; AMF129970, 129975, Reserve Quarry.

Discussion

The abundant Nymboida leaves that are placed in this complex often form 'autumnal banks' on some horizons at both Coal Mine and Reserve Quarries. They are variable in size and manner of dissection and are generally smaller than leaves of *S. schenckii* sensu stricta from the Molteno of South Africa (Anderson and Anderson 1989, 2003). The enlarged specimen illustrated in Fig. 21E shows portions of three leaves attached to a stem. The leaf assemblage on Fig. 22D displays leaves showing a wide range of dissection.

Sphenobaiera leaves which form the most commonly occurring element in the Middle Triassic Benolong Flora of central western New South Wales were described by Holmes (1982) as a new species *S. ugotheriensis*. That taxon was synonymised with *S. schenckii* by Anderson and Anderson 1989. The Benolong leaves are generally longer than *S. schenckii* and, in many cases, with much broader terminal segments (Holmes 1982, Fig. 10C). We consider that *S. ugotheriensis* should stand as a valid species.

Sphenobaiera sectina Anderson and Anderson 1989

Figures 24A; 25A,B

Holotype

Sphenobaiera sectina Anderson and Anderson 1989, Specimen BP/2/824

Selected reference

1989 *Sphenobaiera sectina* Anderson and Anderson p.143, pl.64.

Description

Medium-sized *Sphenobaiera* leaves, 90–120 mm long, c. 40 mm wide, diverging at c. 30° from a short stout petiolate base 5–20 mm long, 0.3–4 mm wide. Lamina with shallow to deep median incision to form two long lanceolate segments with rounded apices; veins forking in proximal third of the lamina and then running straight and parallel to distal margin, venation indistinct to well-defined at 8–12/10 mm across distal portion of segments.

Material

AMF126857, AMF125102, Coal Mine Quarry; AMF125101, Reserve Quarry.

Discussion

The rare Nymboida specimens are similar in shape, size and venation to the once-divided leaves of *S. sectina* from South Africa illustrated by Anderson and Anderson 1989 Pl.63 figs 1–7, Pl.64 figs 3–6,11,12. Cuticle of some of the South African material has been preserved and described.

Sphenobaiera nymbolinea Holmes and Anderson sp. nov.

Figures 26A–C; 27A, 28A.

Diagnosis

Large *Sphenobaiera* leaf, lamina narrowly diverging and bifurcating proximally into c. 16 long linear segments.

Description

Leaf as preserved 145 mm long and probably to 200 mm when complete, 50 mm wide, bifurcating four times in proximal third of leaf to form 16 linear segments each 1–1.5 mm wide; angle of divergence of the lamina from the stout sessile base c. 25°; veins not visible but with possible midrib and longitudinal striations.

Holotype

AMF125104, Australian Museum, Sydney.

Type Locality

Coal Mine Quarry, Nymboida. Basin Creek Formation, Nymboida Coal Measures, Middle Triassic.

Other material

AMF125105, Coal Mine Quarry; AMF125106 and counterpart AMF125107, Reserve Quarry.

Name derivation

Contrived from type locality and the linear ultimate leaf segments.

Discussion

The only material of this taxon collected to date is two individual leaves and a slab and its counterpart bearing stems and leaves. *S. nymbolinea* is similar in form but twice the size of a specimen from the Ipswich Coal Measures referred to *Czekanowskia tenuifolia* by Jones and deJersey (1947 Text fig.55) and also illustrated by Hill et al. (1965 pl.T9 fig.2). In form *S. nymbolinea* lies between the much smaller *S. pontifolia* Anderson and Anderson (1989) with eight segments and *S. africana* (Baldoni 1980) Anderson and Anderson (1989) with 32 segments. The part and counterpart surfaces of the slab illustrated in Figures 26C, 27A and 28A show a mass of leaves probably attached to the lateral axis of the main stem. Unfortunately the crucial points of attachment are not clear on either surface.

Sphenobaiera sp. cf. _S. browniana_ Anderson and Anderson 1985

Figures 29A, 30A,B

Description

Large incomplete acutely wedge-shaped *Sphenobaiera* leaves; estimated length from 200 mm to 350 mm; lamina deeply incised to form four or more long parallel-sided segments from 15–20 mm wide; apices not preserved; veins bifurcating near the base then running straight and parallel towards the apex, coarse, 5–8/10 mm across distal width of segments.

Material

AMF125108, 125110, Coal Mine Quarry; AMF125109, Reserve Quarry.

Discussion

By their large size and long strap-like segments these uncommon Nymboida leaves are compared with *S. browniana*, a species known only from three incomplete leaf fragments from the Burgersdorp Formation of South Africa (Anderson and Anderson 1983 p.156, 157, pl. 184; 1989 p.147). The South African leaves are significantly larger being more than 400 mm long, with assymetrical dissection and unclear venation.

The surface of the slab illustrated in Figure 29A shows an assemblage of several incomplete leaves. The largest leaves of the Nymboida '*S. stormbergensis* complex' (Figure 12B, 13A) have long parallel-sided segments but they are less than 200 mm long and have denser venation than those of *S.* sp. cf. *S. browniana*.

Sphenobaiera sp. A

Figures 25C,D

Description

A very small incomplete leaf c. 20 mm long, 25 mm wide, base missing; angle of divergence c. 90°; lamina divided almost to the base into eight straight-sided segments expanding distally. Veins are conspicuous, bifurcating occasionally to run straight and parallel to the segment margins; vein density near segment apices c. 45/10 mm.

Material

AMF125103, Coal Mine Quarry.

Discussion

From its small size and very dense venation, this leaf differs from all previously described ginkgophyte leaves. However better preserved material is needed to adequately describe this leaf form as a new species.

Fructifications associated with Ginkgophyte leaves

From their large collections of Late Triassic plants from the Molteno Formation of South Africa, Anderson and Anderson (2003) have evidence with varying degrees of certainty on the affiliation or attachment of fertile organs with Ginkgophyte-like leaves. The female strobilus *Avatia* and the male strobilus *Eosteria* are regarded as the fertile organs of plants bearing *Ginkgoites* leaves. Neither *Avatia* nor *Eosteria* organs have, so far, been collected at Nymboida. From the Molteno Formation both the female (*Hamshawvia*) and male (*Stachyopitys*) reproductive structures have been found in organic attachment with *Sphenobaiera* leaves. On the basis of their unique differences to other Gondwana Triassic ovulate genera Anderson and Anderson (2003) have placed the *Ginkgoites* and *Sphenobaiera* genera in separate families and orders. While specimens of both *Hamshawvia* and *Stachyopitys* are present in the Nymboida collections, neither are found in organic attachment but do occur in close association with *Sphenobaiera* leaves (Figs 10D,E, 31A–C). The slab from Nymboida bearing two *Hamshawvia* receptacles was illustrated but not described in Holmes (1996).

Genus Hamshawvia Anderson and Anderson 2003

Type species

Hamshawvia baccata Anderson and Anderson 2003 p.214

Hamshawvia distichos Holmes and Anderson sp. nov.

Figures 10D,E; 31A–C

Reference

1996 'paired ovulate organ' Holmes Pl.1.1

Diagnosis

A large *Hamshawvia strobilus* with paired broad-ovate fleshy megasporophylls bearing two rows of embedded ovules on either side of the midrib.

Description

Peduncle stout 17 mm long, base missing, 2.5 mm wide, longitudinally striated, bifurcating into short tapering pedicels c. 5 mm and 8 mm long, each bearing a single terminal fleshy broad-ovate receptacle c. 18 mm long, 15 mm wide, margins entire, apices rounded; dorsal surface (Fig. 31A) showing a stout median vein with c. six lateral veins on either side departing at an acute angle, arching and dividing into three proximally and two distally; ventral surface (Fig. 31B,C) carbonaceous, revealing two rows of embedded ovules on either side of midrib, the outer row with c. eight ovules, the inner row with c. four; ovules rounded, c. 1 mm in diameter.

Holotype

AMF129946 and counterpart AMF129950, Australian Museum, Sydney.

Type Locality

Coal Mine Quarry, Nymboida. Basin Creek Formation, Nymboida Coal Measures, Middle Triassic.

Other material

AMF130176 and counterpart AMF130177 on same slab as holotype and its counterpart.

Name derivation

distichos (Greek) two rows, referring to the two rows of ovules on either side of the receptacle midrib.

Discussion

Only the holotype (Fig. 31 A,C) and one other strobilis, both on the same slab (Fig. 10A and 10E) and their counterparts have been collected. They are very similar and were possibly derived from the same but unknown parent plant.

Hamshawvia distichos differs from all Molteno *Hamshawvia* spp by its larger size, and by the greater number of ovules which are arranged in two rows on either side of the midrib. *Stiphorus*, a genus of ovulate organs from the Late Permian of Eurasia (Gomankov and Meyen 1980; Meyen 1987) is similar in gross morphology to *Hamshawvia* but differs by the external attachment of the ovules. The strobili of *Hamshawvia distichos* cannot be affiliated with any specific leaf type as they are preserved on a bedding plane of coarse grey shale in close association with three distinct morpho-species of *Sphenobaiera* leaves (Fig. 10).

Hamshawvia sp. A

Figures 32A,B

Description

A small *Hamshawvia* with an elongated slender peduncle 18 mm long (as preserved), 1 mm wide, bifurcating to form two pedicels (one missing); the preserved pedicel arching and expanding into the base of a reniform to semi-circular megasporophyll 6 mm long, 8 mm wide; margin entire; apex rounded; surface verrucose; no venation or ovules visible.

Material

AMF125111, Coal Mine Quarry, Nymboida.

Discussion

This single small incomplete specimen is obviously a *Hamshavia* but as the presence of ovules in the receptacle cannot be determined it has not been formally named. It is preserved in fine white sandstone together with fragments of ferns. The shape and surface texture of *H.* sp. A is somewhat similar to *H. longipedunculata* from the Molteno Formation (Anderson and Anderson 2003 p.215, pl.70, figs 1,4,5) but lacks evidence of the embedded ovules that are arranged radially about the midvein in that species.

Genus *Stachyopitys* Schenck 1867

Type species

Stachyopitys preslii Schenck from Bavaria, Germany, Triassic.

A specimen with a strobilis of *Stachyopitys lacrisporanga* and a leaf of *Sphenobaiera africana* attached to a common bulbous base (Anderson and Anderson 2003 pl.81(1–3)) from the Molteno Formation of South Africa has confirmed the affiliation of *Stachyopitys* as the male fructification of the plant bearing *Sphenobaiera* leaves.

***Stachyopitys* sp. cf. *S. matatilongus* Anderson and Anderson 2003**
Figures 33A–D, 34A, E

Description

The male strobilus (Fig. 33A) is c. 24 mm long, base and apex missing, axis c. 1 mm wide, with spirally attached pedicels 2–2.5 mm long, branching and bearing terminal radial clusters of 5–8 elliptical microsporangia each c. 1.5 mm long, 0.5 mm wide.

Material

AMF125112–5, Coal Mine Quarry.

Discussion

The rare specimens of *S.* sp. cf. *S. matatilongus* from Nymboida are closely similar to the Molteno specimens of *S. matatilongus* by the elongated strobili bearing clusters of microsporangia borne on branching pedicels, but differ by the straight elliptic shape of the microsporangia. Shirley (1898) described two species of *Stachyopitys* from the Ipswich Coal Measures of Queensland as *S. annularoides* and *S. simmondsii.* Anderson and Anderson (2003) regarded *S. annularoides* of Shirley as a species of *Pteruchus* but agreed that the dispersed microsporangia described in Walkom (1917) as *S. annularoides* were indeed *Stachyopitys.* The microsporangial clusters of Walkom are similar to the Nymboida *S.* sp. cf. *S. matatilongus. S. simmondsii* differs from *S.* sp. cf. *S. matatilongus* by its much smaller size and from *S.* sp. cf. *S. lacrisporangia* (below) by the shape of the microsporangia.

***Stachyopitys* sp. cf. *S. lacrisporangia* Anderson and Anderson 2003**
Figures 34B–D

Description

A fragment of a strobilus (Fig. 34B) bearing four microsporophylls and five detached microsporophylls (Fig.34 C,D), each a radial cluster of c. 10 tear-shaped microsporangia, c. 1 mm long.

Material

AMF126855–6, Coal Mine Quarry.

Discussion

This fragmentary Nymboida material has microsporophylls with tear-shaped microsporangia similar to, but larger than those of *S. lacrisporangia* from the Molteno Formation and the complete strobilus is not known.

CONCLUSION

We have endeavoured to illustrate the full range of Nymboida Ginkgophyta to enable meaningfull comparisons with future collections. Leaves collected from the Basin Creek Formation of the Nymboida Coal Measures have been placed, on the basis of gross morphology, into the morpho-genera *Ginkgoites* (with 4 spp.) and *Sphenobaiera* (with 8 spp). Where numerous specimens of a particular form were available to show the range of variation we have referred to that taxon as a 'morpho-species complex' eg. '*Ginkgoites denmarkensis* complex'. Seven of our species compare well with previously described species from the Gondwana Triassic flora. We have described one new species of *Ginkgoites* and three new species of *Sphenobaiera.* Comparisons have mainly been made with the recently reviewed Ginkophyte floras from the El Tranquilo Flora of Patagonia (Gnaedinger and Herbst 1999) and the comprehensively collected and described Molteno Formation of South Africa (Anderson and Anderson 1989, 2003). The presence of *Hamshawvia distichos* and *H.* sp. A are the first descriptions of Ginkgophyte ovulate structures from Australia. Two species of *Stachyopitys* are compared with Molteno material.

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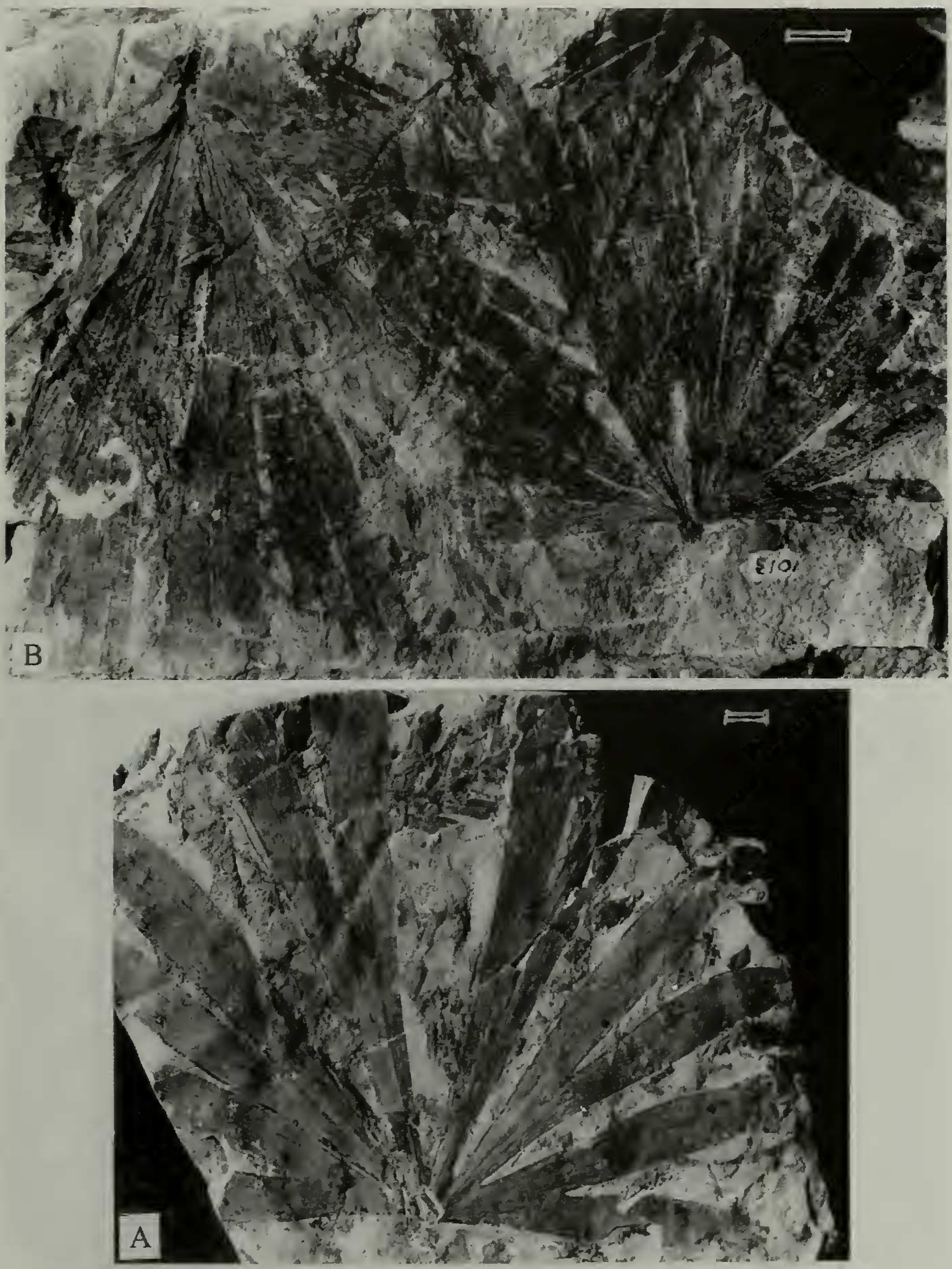

Figure 1. A,B. *Ginkgoites nymboidensis* Holmes and Anderson sp. nov. A. AMF129926; B. AMF129927. Both Coal Mine Quarry. Scale bar = 1 cm.

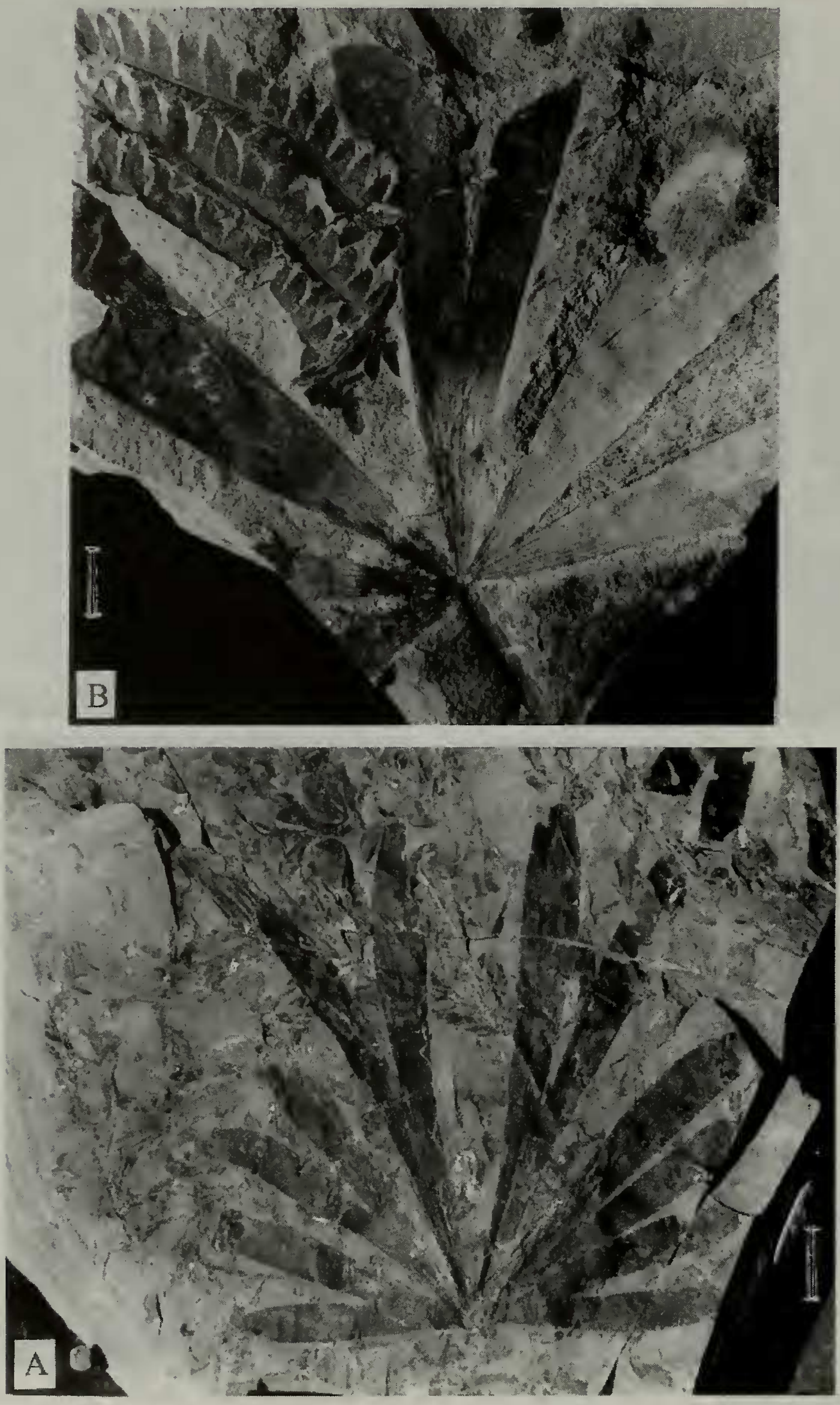

Figure 2. A,B. *Ginkgoites nymboidensis* Holmes and Anderson sp. nov. A. Holotype, AMF129928, Coal Mine Quarry; B. AMF129929, Reserve Quarry. Scale bar = 1 cm.

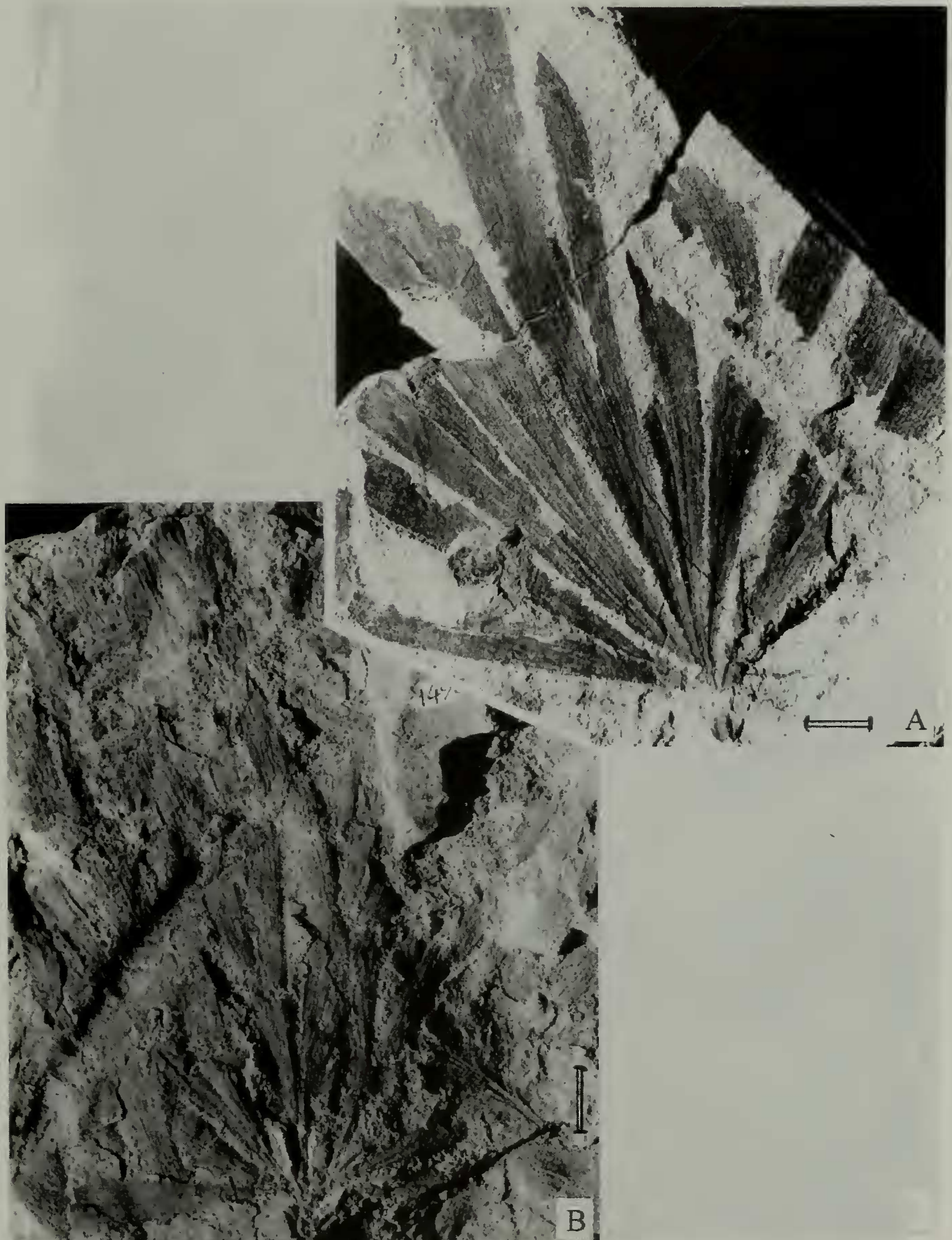

Figure 3. A,B. '*Ginkgoites denmarkensis* complex'. A. AMF129930; B. AMF129931. Both Coal Mine Quarry. Scale bar = 1 cm.

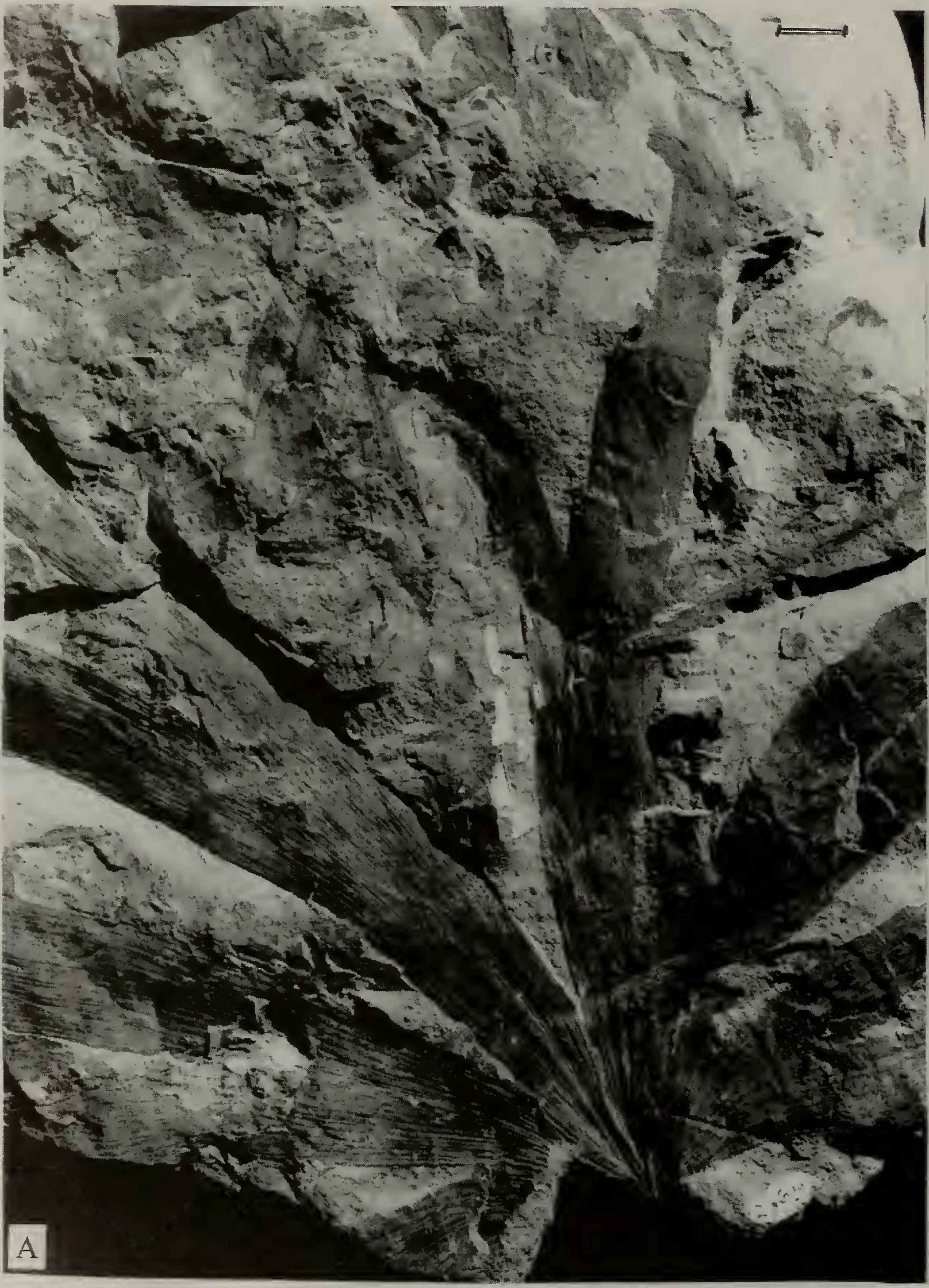

Figure 4. A. '*Ginkgoites denmarkensis* complex'. AMF129932. Coal Mine Quarry. Scale bar = 1 cm.

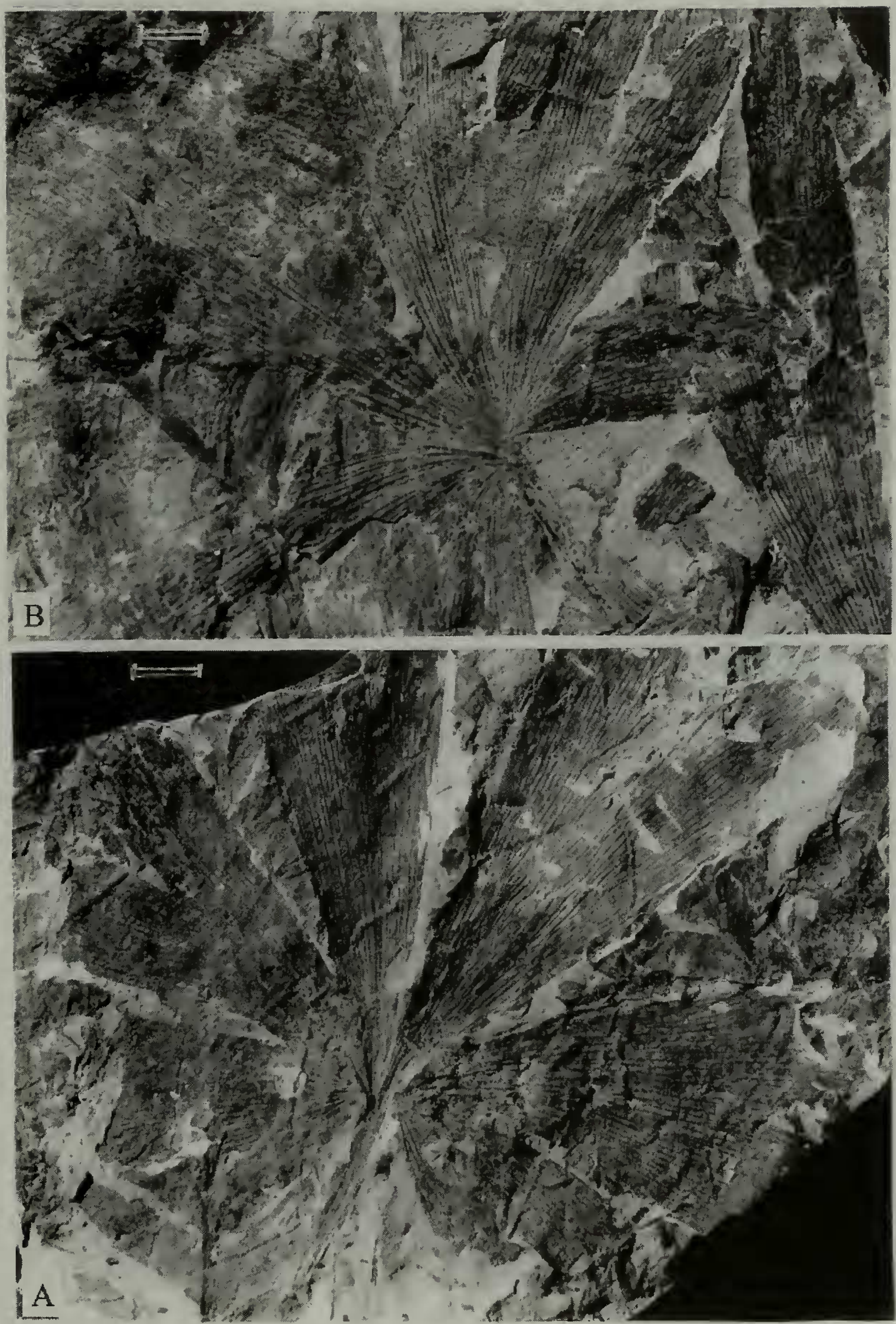

Figure 5. A,B. '*Ginkgoites denmarkensis* complex'. A. AMF129933; B. AMF129934. Both from Coal Mine Quarry. Scale bar = 1 cm.

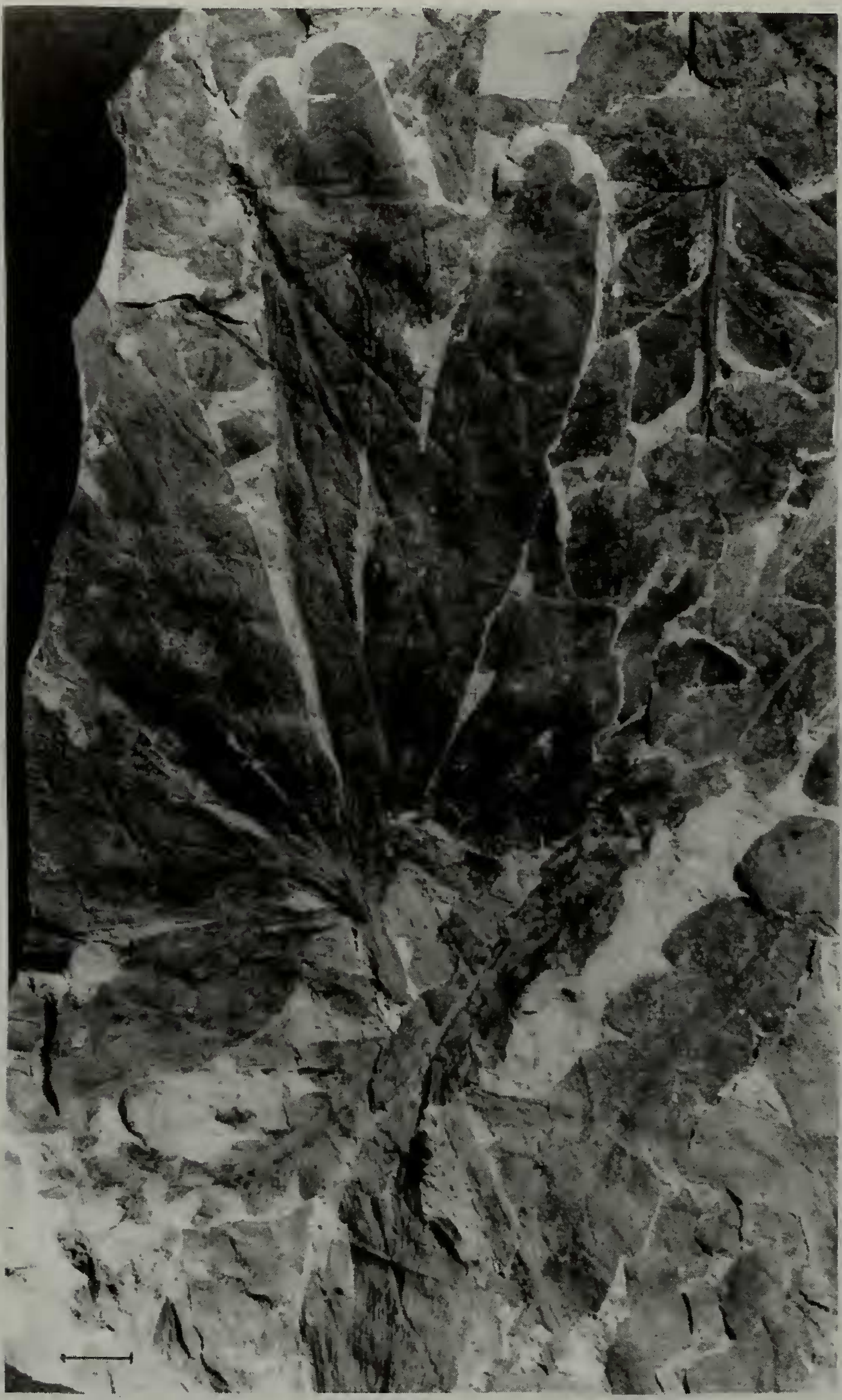

Figure 6. A. '*Ginkgoites denmarkensis* complex'. AMF129935. Reserve Quarry. Scale bar = 1 cm.

Figure 7. A. '*Ginkgoites denmarkensis* complex'. AMF129936. Coal Mine Quarry. Scale bar = 1 cm.

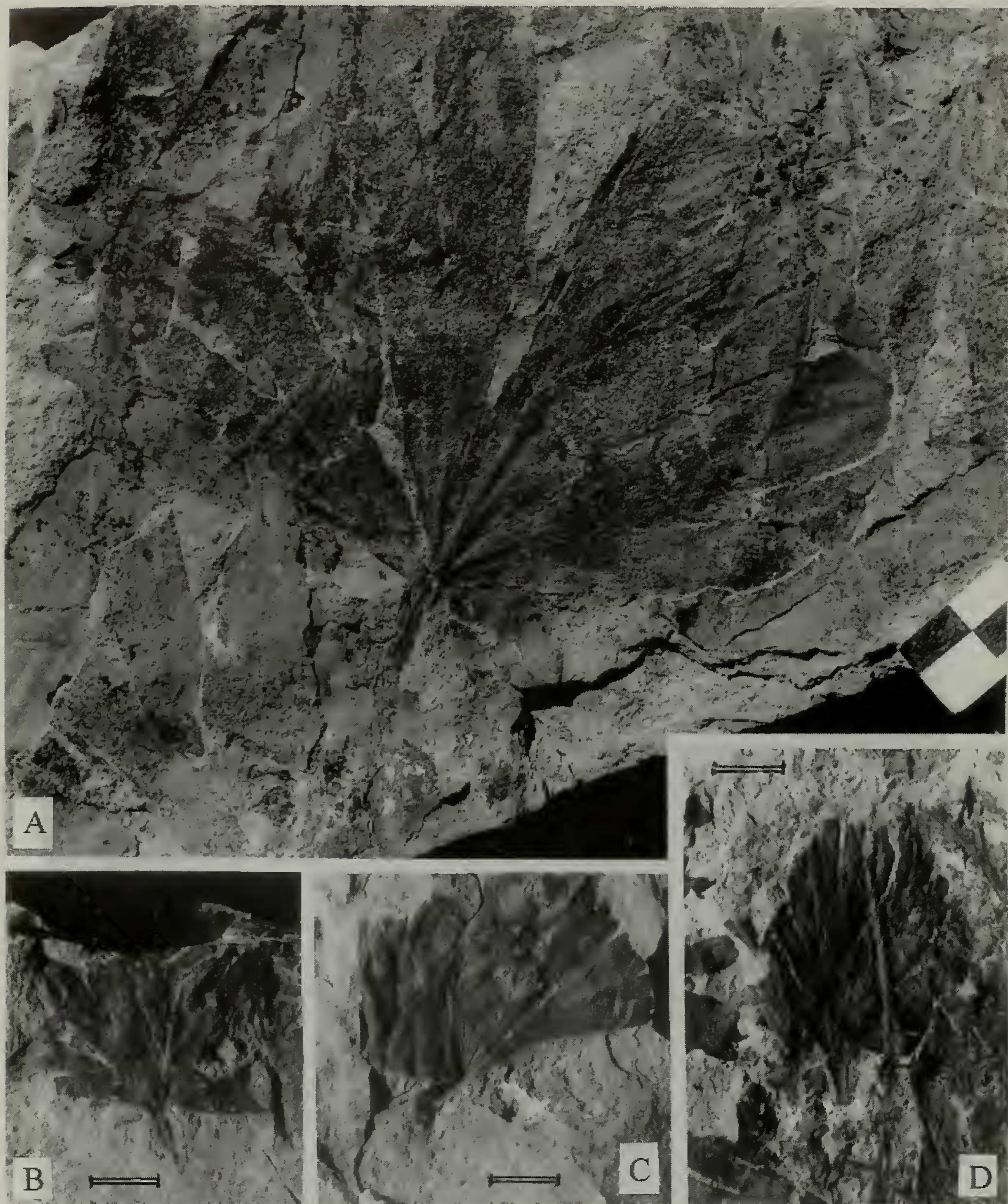

Figure 8. A. '*Ginkgoites denmarkensis* complex'. AMF129937. Coal Mine Quarry; B–D. *Ginkgoites* sp. cf. *G. waldeckensis* (Anderson and Anderson) Gnaedinger and Herbst. B. AMF129938. C. AMF129939. D. AMF129940. B, D, Coal Mine Quarry; C, Reserve Quarry. Scale bar = 1 cm.

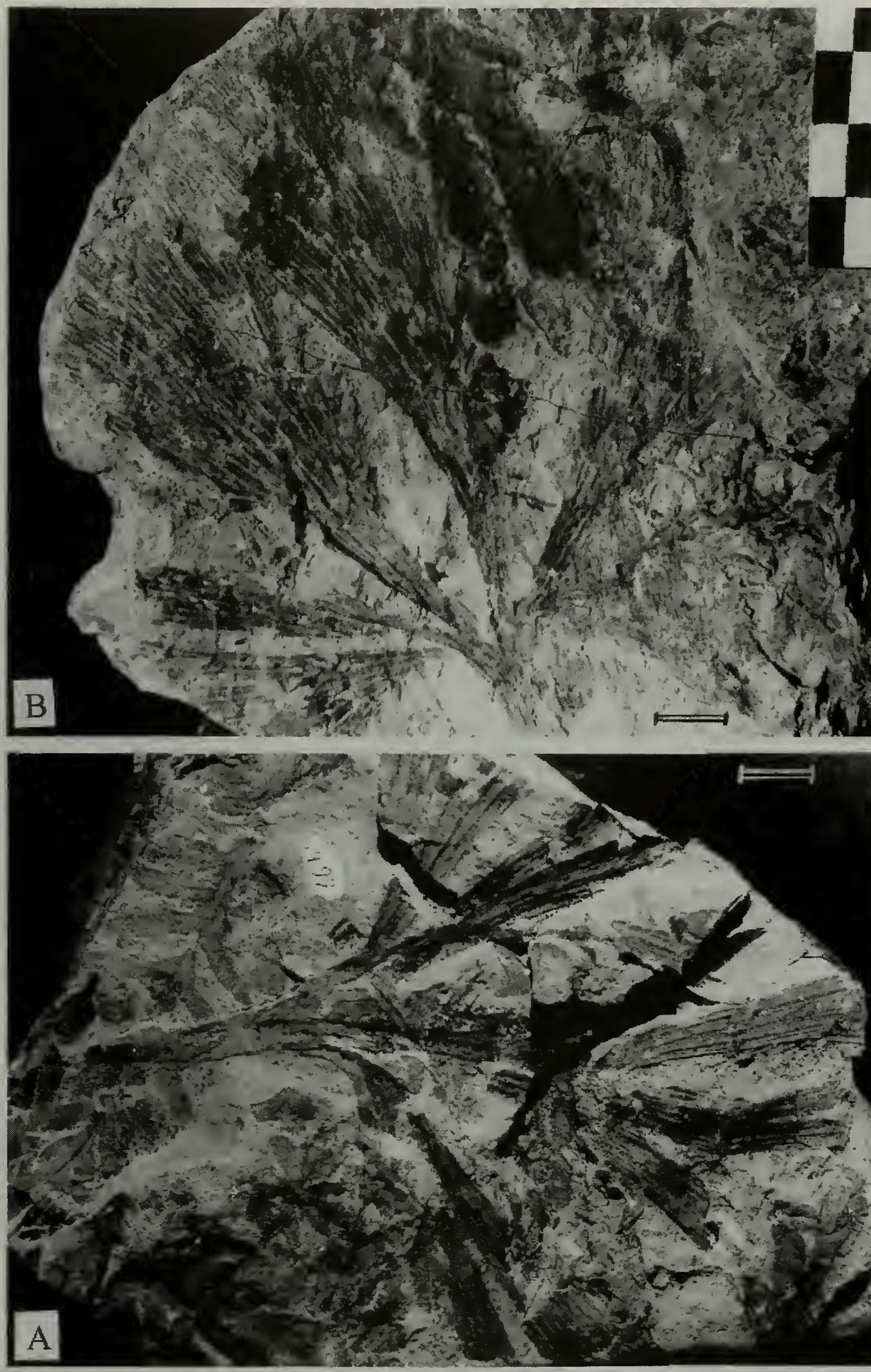

Figure 9. A,B. *Ginkgoites ginkgoides* (Shirley) Holmes and Anderson comb. nov. A. AMF129941; B. AMF129942. Both Coal Mine Quarry. Scale bar = 1 cm.

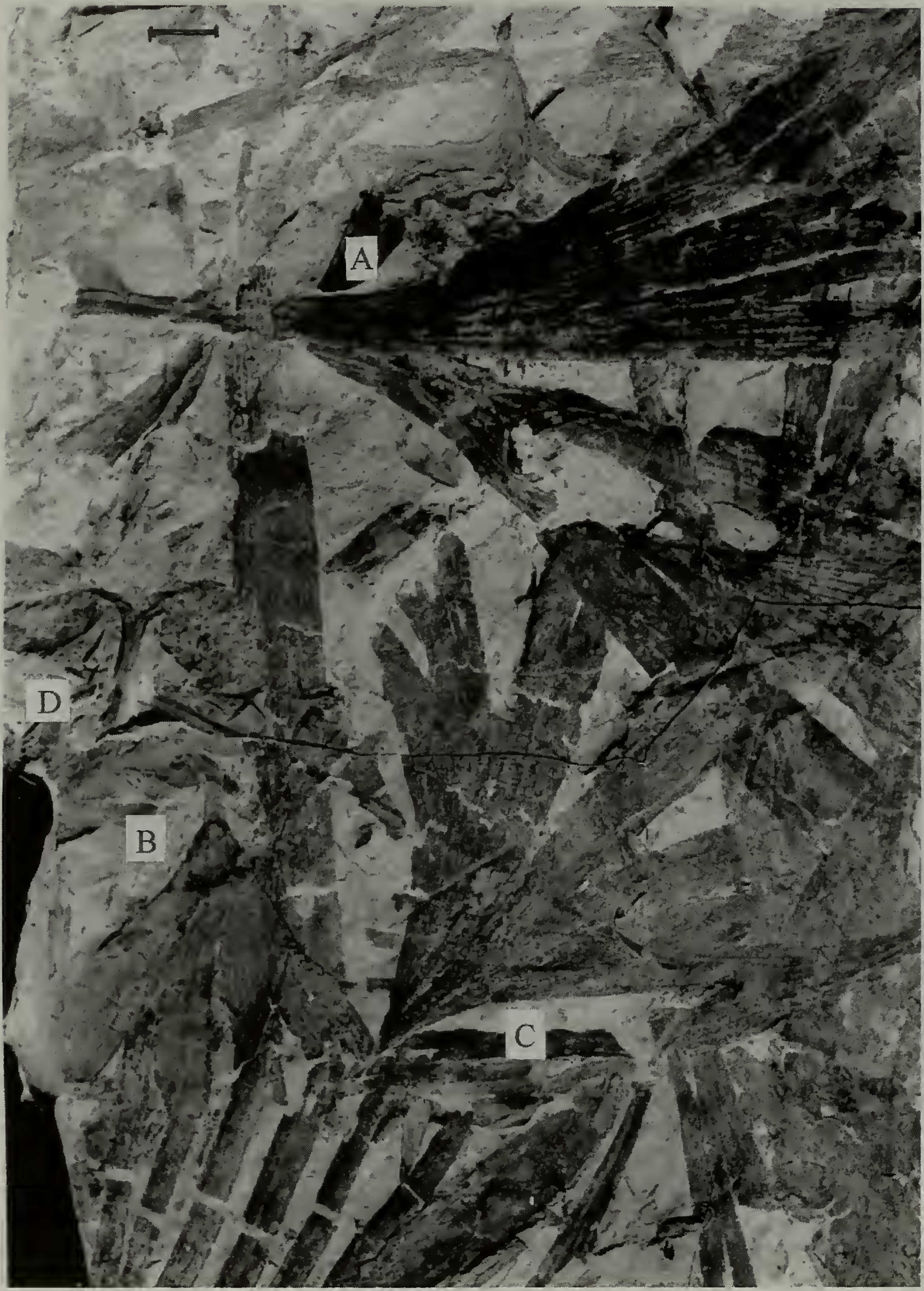

Figure 10. Ginkophyte assemblage on one bedding plane from Coal Mine Quarry. A. '*Sphenobaiera stormbergensis* complex' AMF129943; B. *Sphenobaiera paucinerva* Holmes and Anderson sp. nov. AMF129944; C. '*Sphenobaiera densinerva* complex' Holmes and Anderson sp. nov. Holotype AMF129945; D. *Hamshawvia distichos* Holmes and Anderson sp. nov. Holotype AMF129946. E. *Hamshawvia distichos* AMF130176. Scale bar = 1 cm.

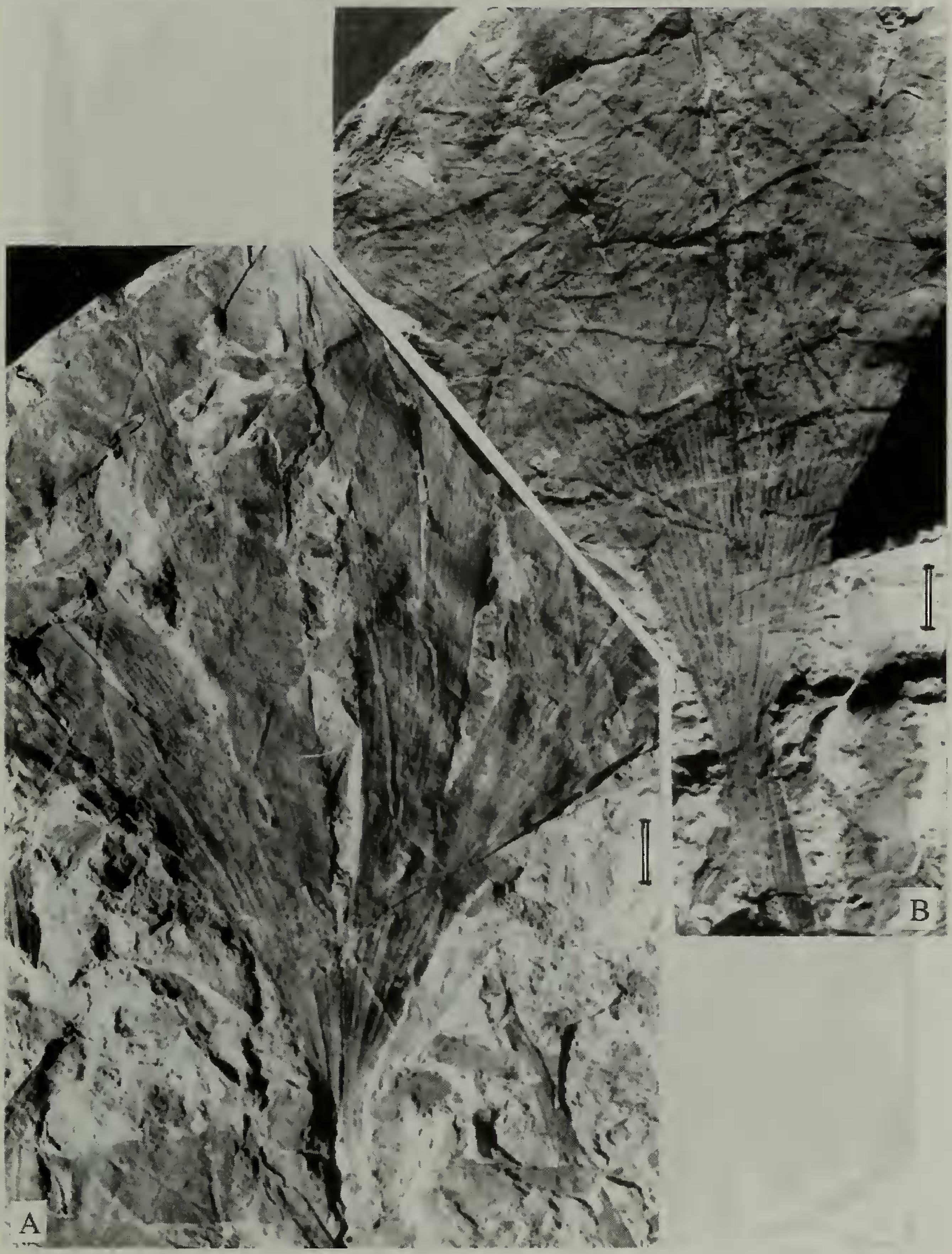

Figure 11. A,B. '*Sphenobaiera stormbergensis* complex'. A. AMF121025; B. AMF121026. Both Coal Mine Quarry. Scale bar = 1 cm.

Figure 12. A,B. '*Sphenobaiera stormbergensis* complex'. A. AMF130168. Reserve Quarry; B. AMF130169. Coal Mine Quarry. Scale bar = 1 cm.

Figure 13. A. '*Sphenobaiera stormbergensis* complex'. AMF129953. Coal Mine Quarry. Scale bar = 1 cm.

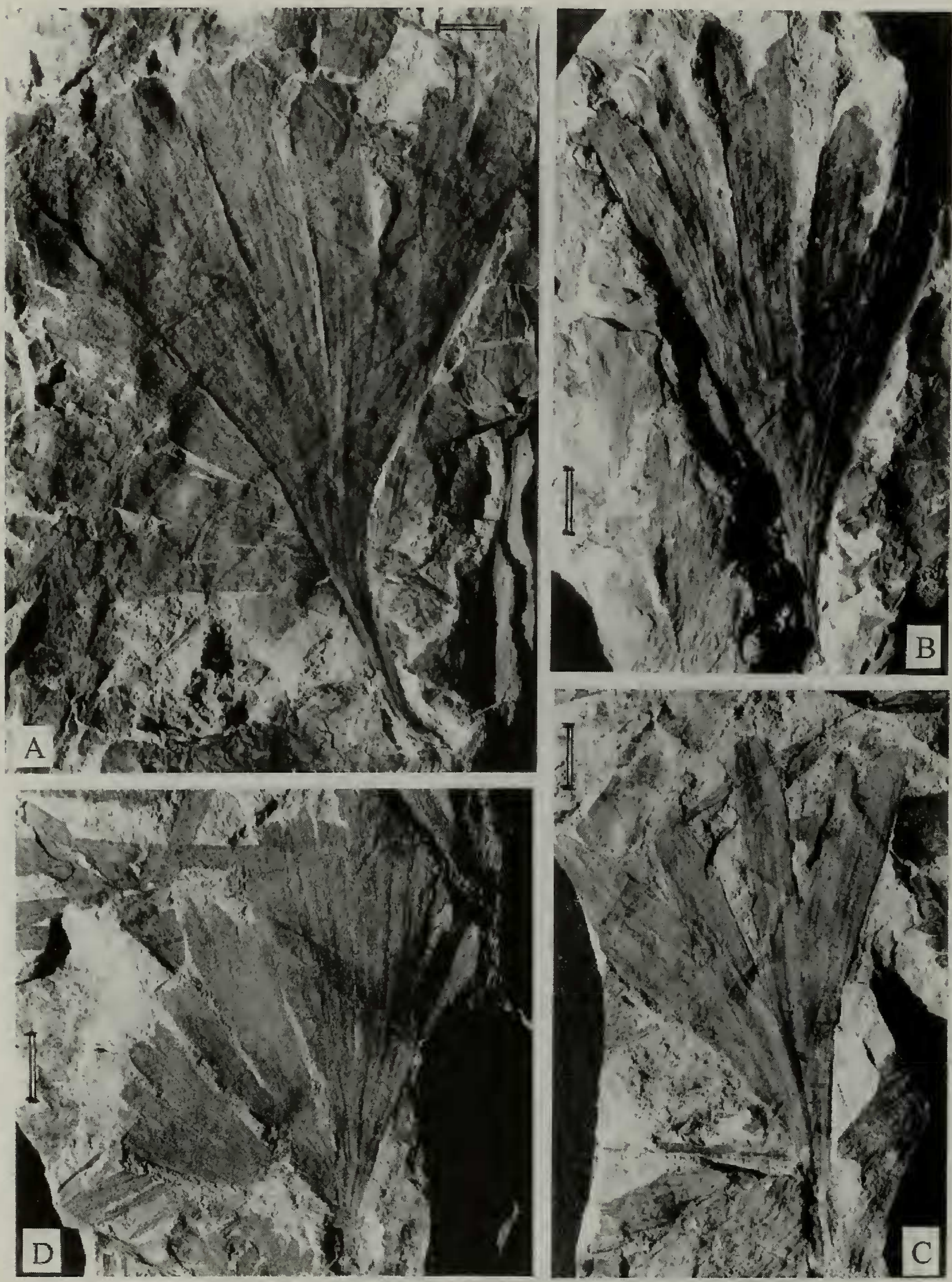

Figure 14. A–D. *Sphenobaiera paucinerva* Holmes and Anderson sp. nov. A. Holotype. AMF129954; B. AMF129955; C. AMF129956; D. AMF129957. All Coal Mine Quarry. Scale bar = 1 cm.

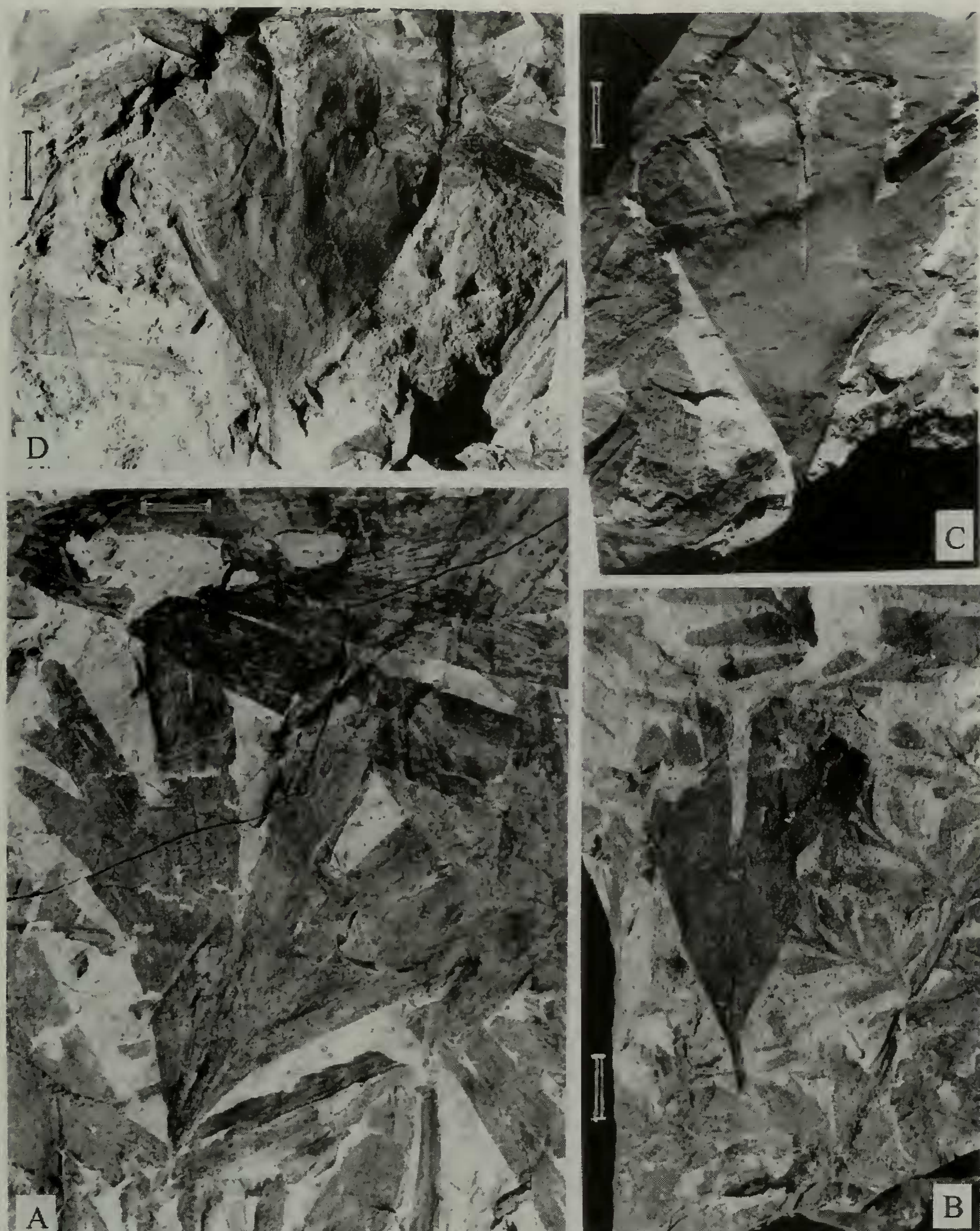

Figure 15. A–D. '*Sphenobaiera densinerva* Holmes and Anderson sp. nov. complex' A. Holotype, AMF129945; B. AMF129959; C. AMF129960; D. AMF129961. All Coal Mine Quarry. Scale bar = 1 cm.

Figure 16. A,B. '*Sphenobaiera densinerva* Holmes and Anderson sp. nov. complex'. AMF129962. B. Arrow showing insect damage. Coal Mine Quarry. Scale bar = 1 cm.

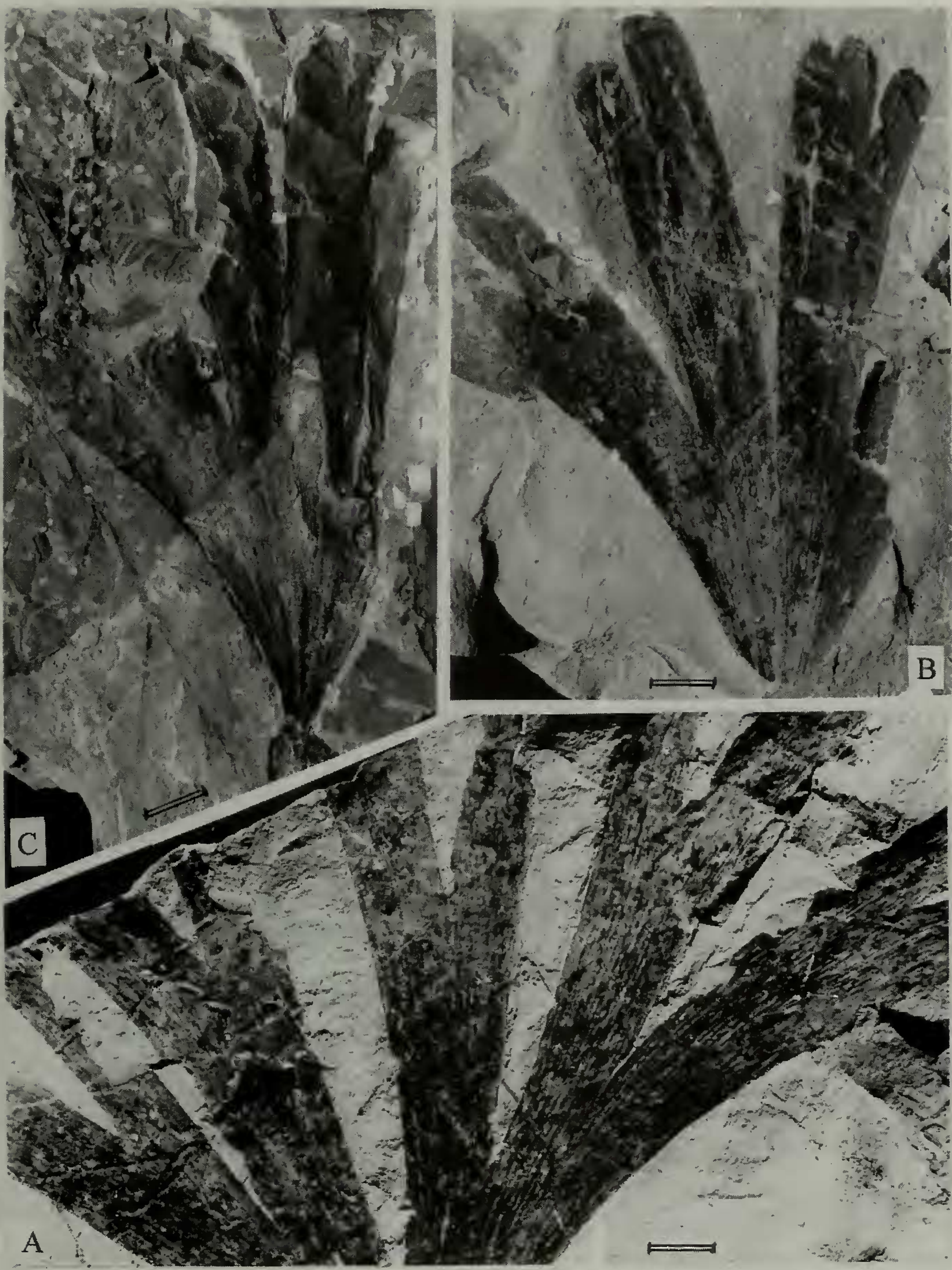

Figure 17. A–C. '*Sphenobaiera densinerva* Holmes and Anderson sp. nov. complex'. A. AMF129963; B. AMF129964; C. AMF129965. All Coal Mine Quarry. Scale bar = 1 cm.

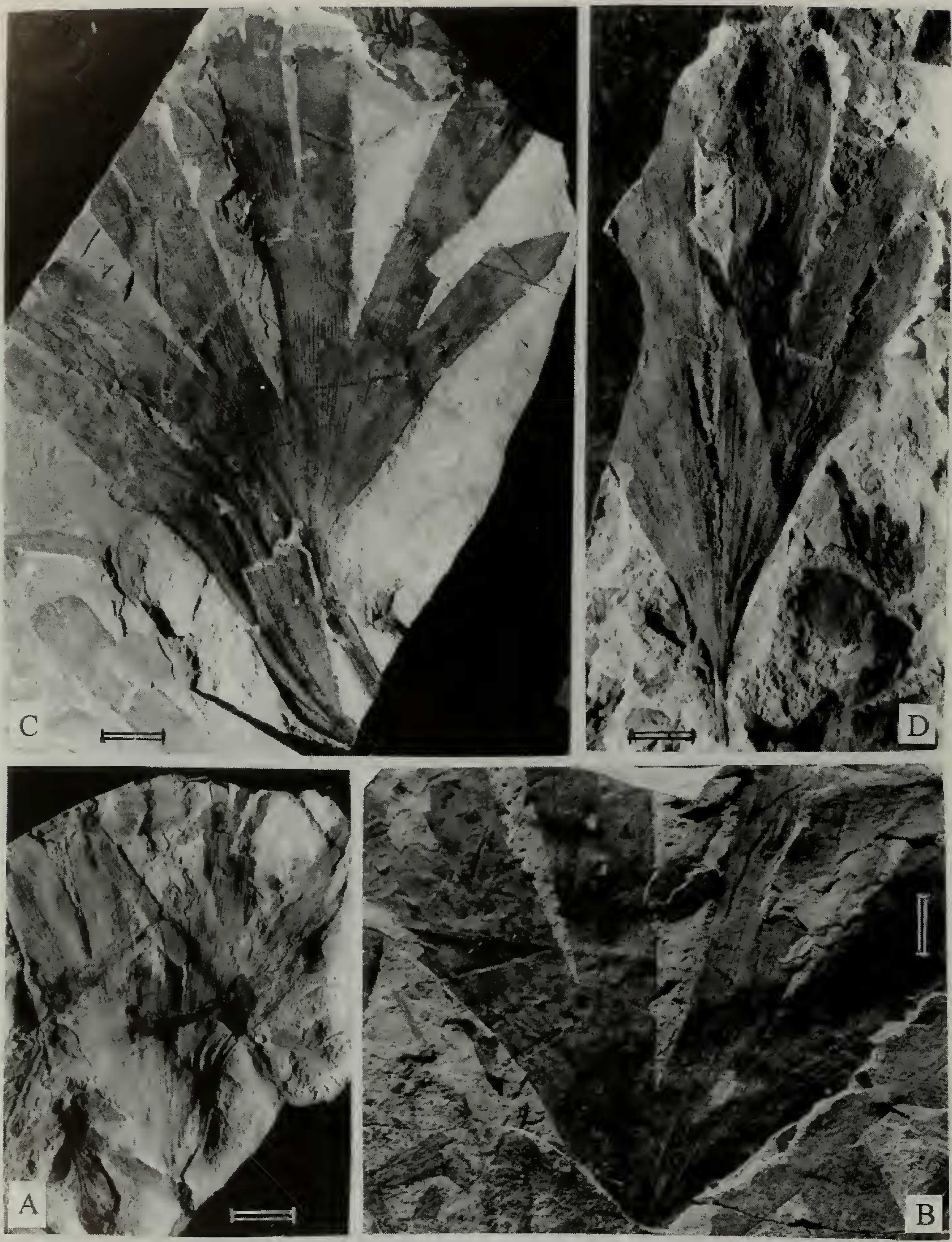

Figure 18. A–D. '*Sphenobaiera densinerva* Holmes and Anderson sp. nov. complex'.A. AMF129966; B. AMF129967; C. AMF129968. All Coal Mine Quarry. D. AMF129969. Reserve Quarry. Scale bar = 1 cm.

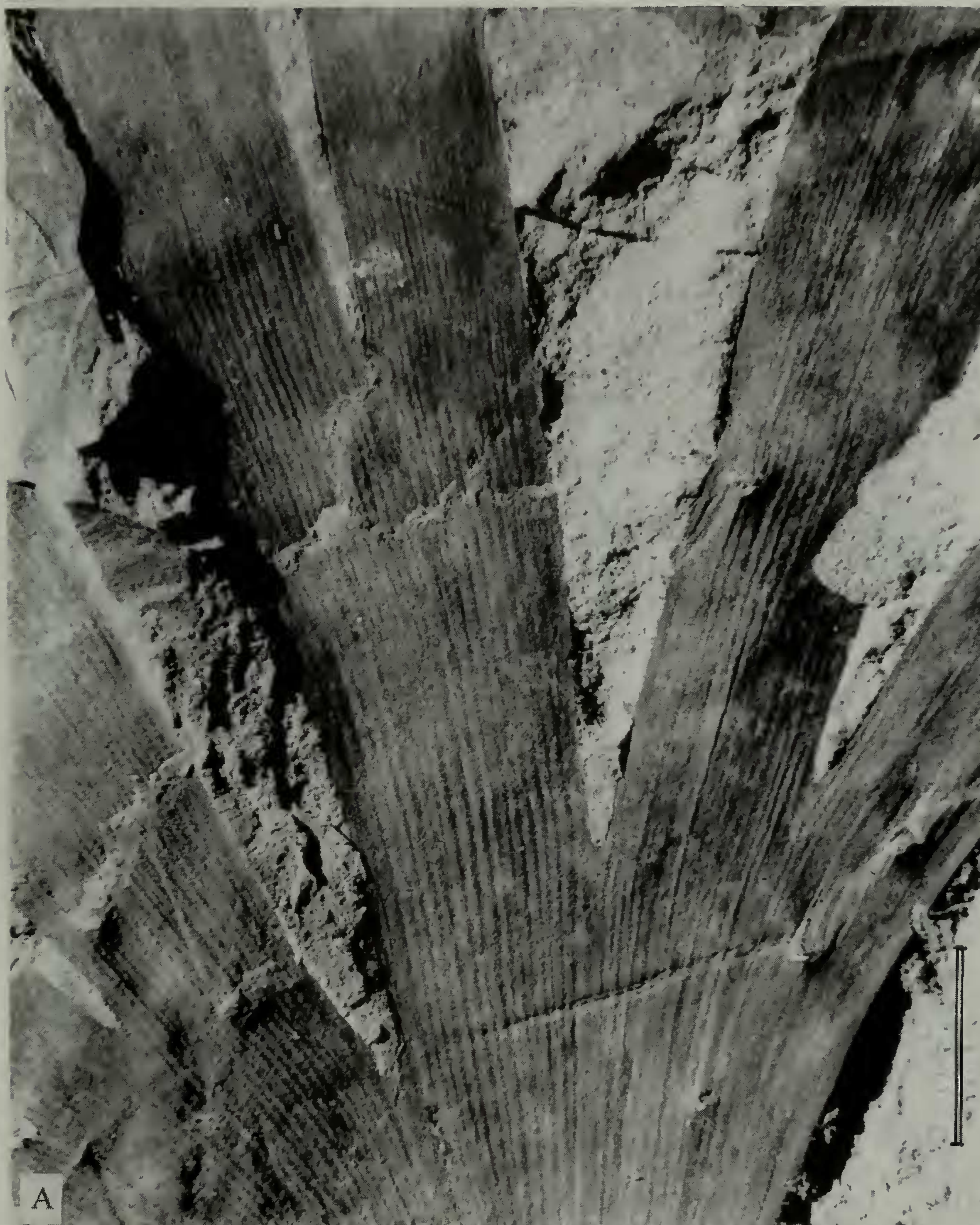

Figure 19. A. '*Sphenobaiera densinerva* Holmes and Anderson sp. nov. complex'. AMF129968, venation pattern. Coal Mine Quarry. Scale bar = 1 cm.

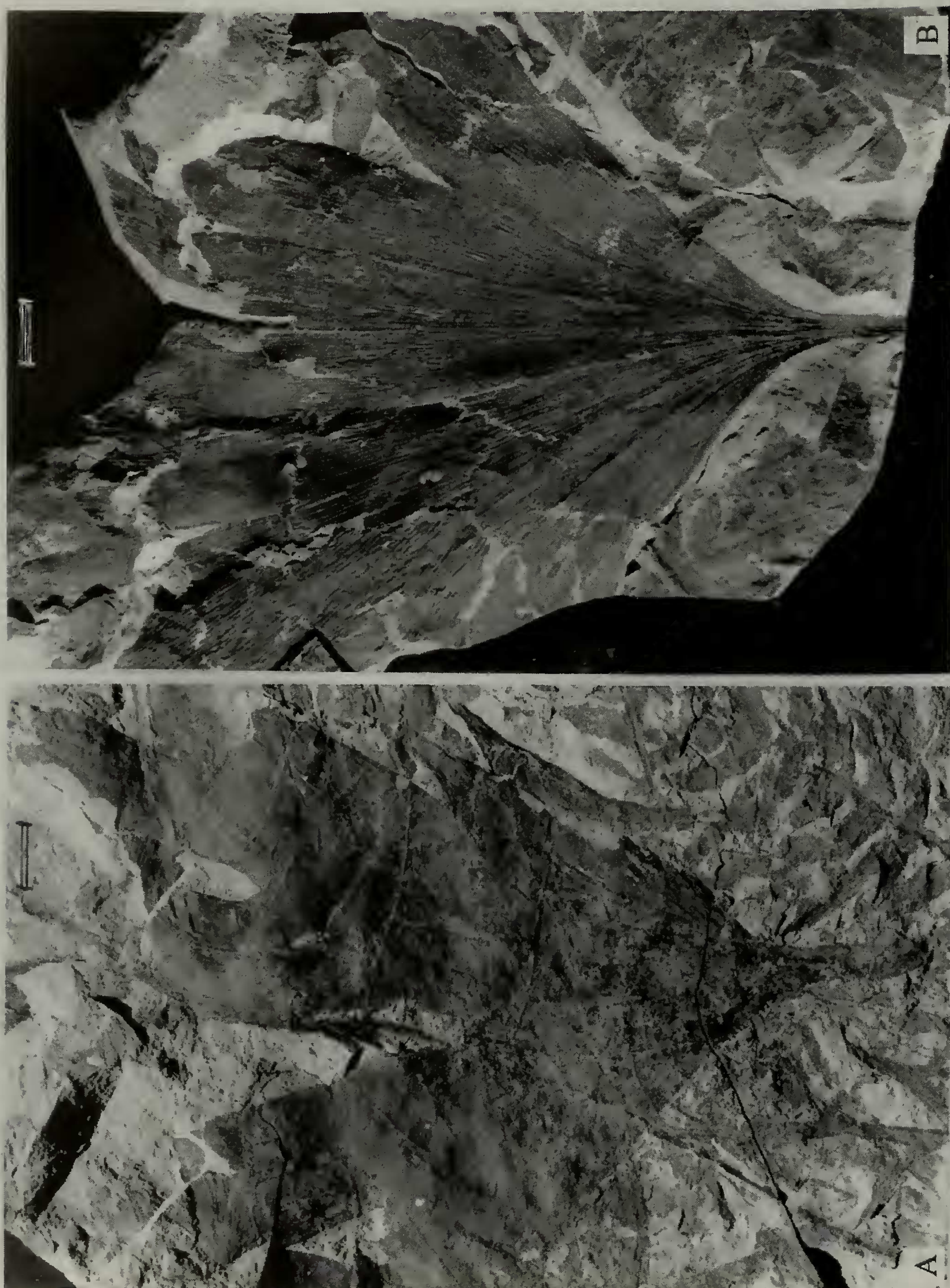

Figure 20. A,B. '*Sphenobaiera densinerva* Holmes and Anderson sp. nov. complex'. A. AMF129971; B. AMF129972. Both Coal Mine Quarry. Scale bar = 1 cm.

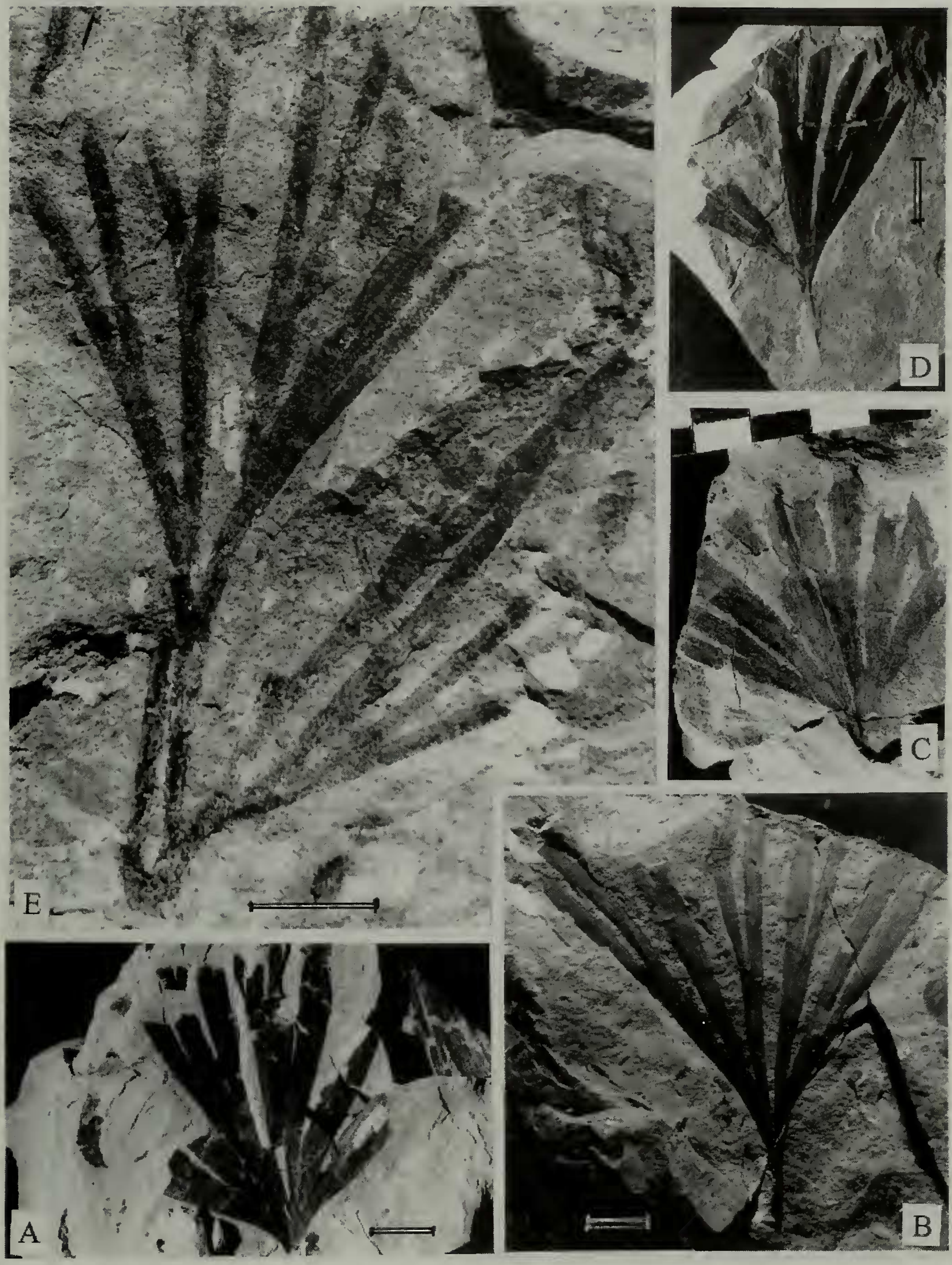

Figure 21. A–E. '*Sphenobaiera schenckii* (*Feistmantel*) Florin complex'. A. AMF129973; B. AMF129974; C. AMF129975; D. AMF129958; E. AMF129970. A,B,D Coal Mine Quarry; C, E Reserve Quarry. Scale bar = 1 cm.

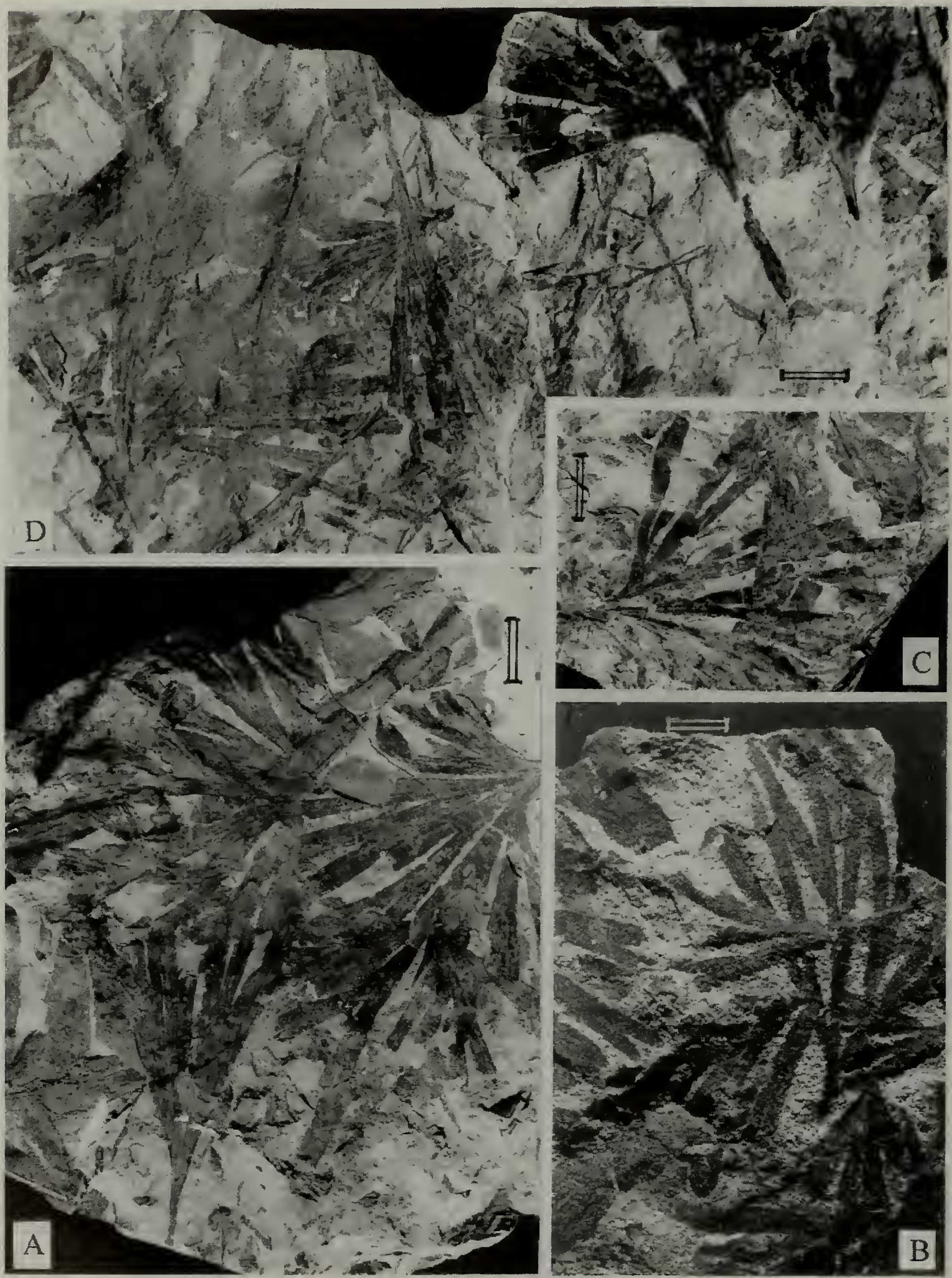

Figure 22. A–D. Leaf assemblages of '*Sphenobaiera schenckii* (Feistmantel) Florin complex'. A. AMF121027; B. AMF121028; C. AMF121029; D. AMF121030. All Coal Mine Quarry. Scale bar = 1 cm.

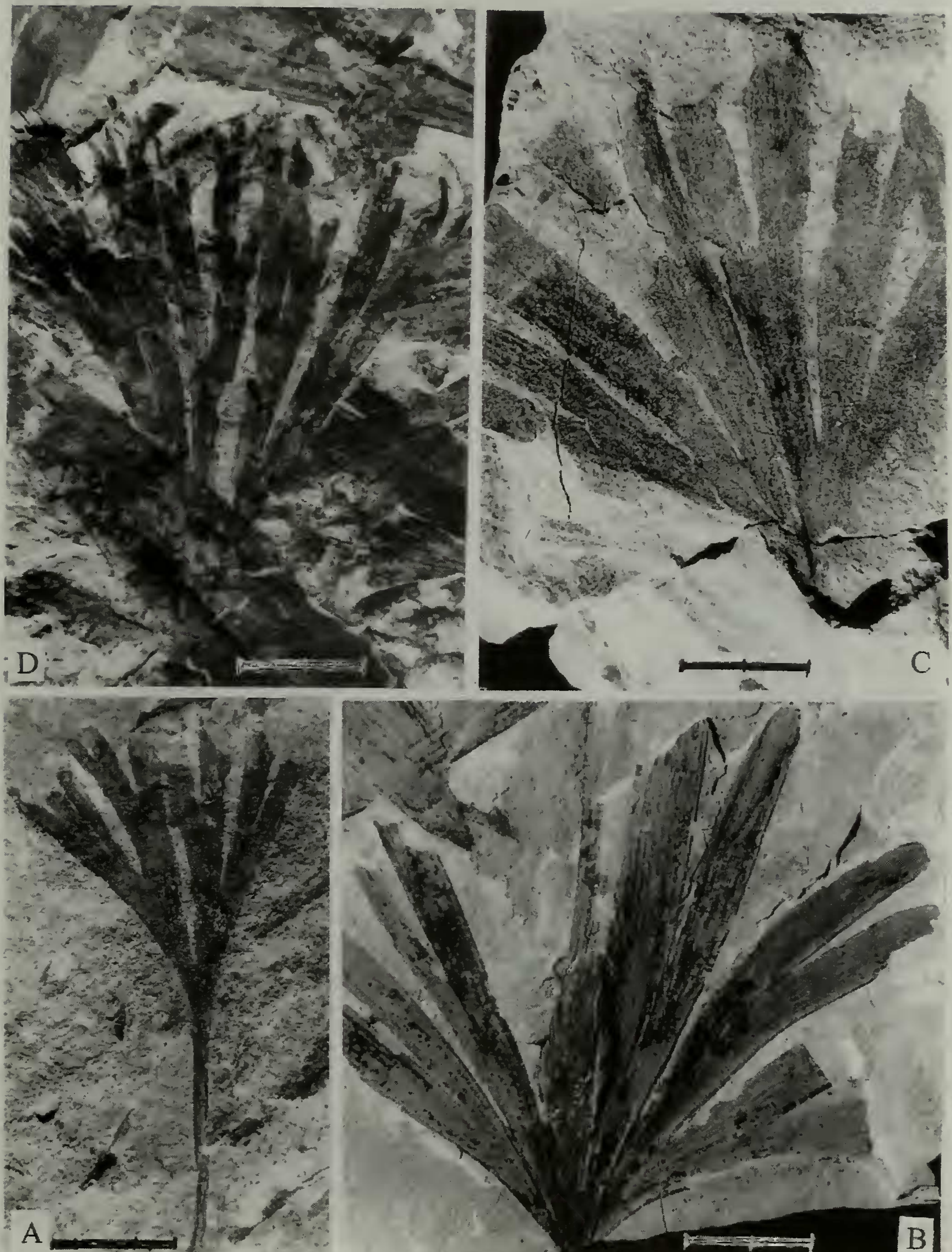

Figure 23. A–D. '*Sphenobaiera schenckii* (Feistmantel) Florin complex'. A. AMF121041; B. AMF121042; C. AMF129975; D. AMF121044. A, B, D Coal Mine Quarry; C Reserve Quarry. Scale bar = 1 cm.

Figure 24. A. *Sphenobaiera sectina* Anderson and Anderson. AMF126857, leaf assemblage. Coal Mine Quarry. Scale bar = 1 cm.

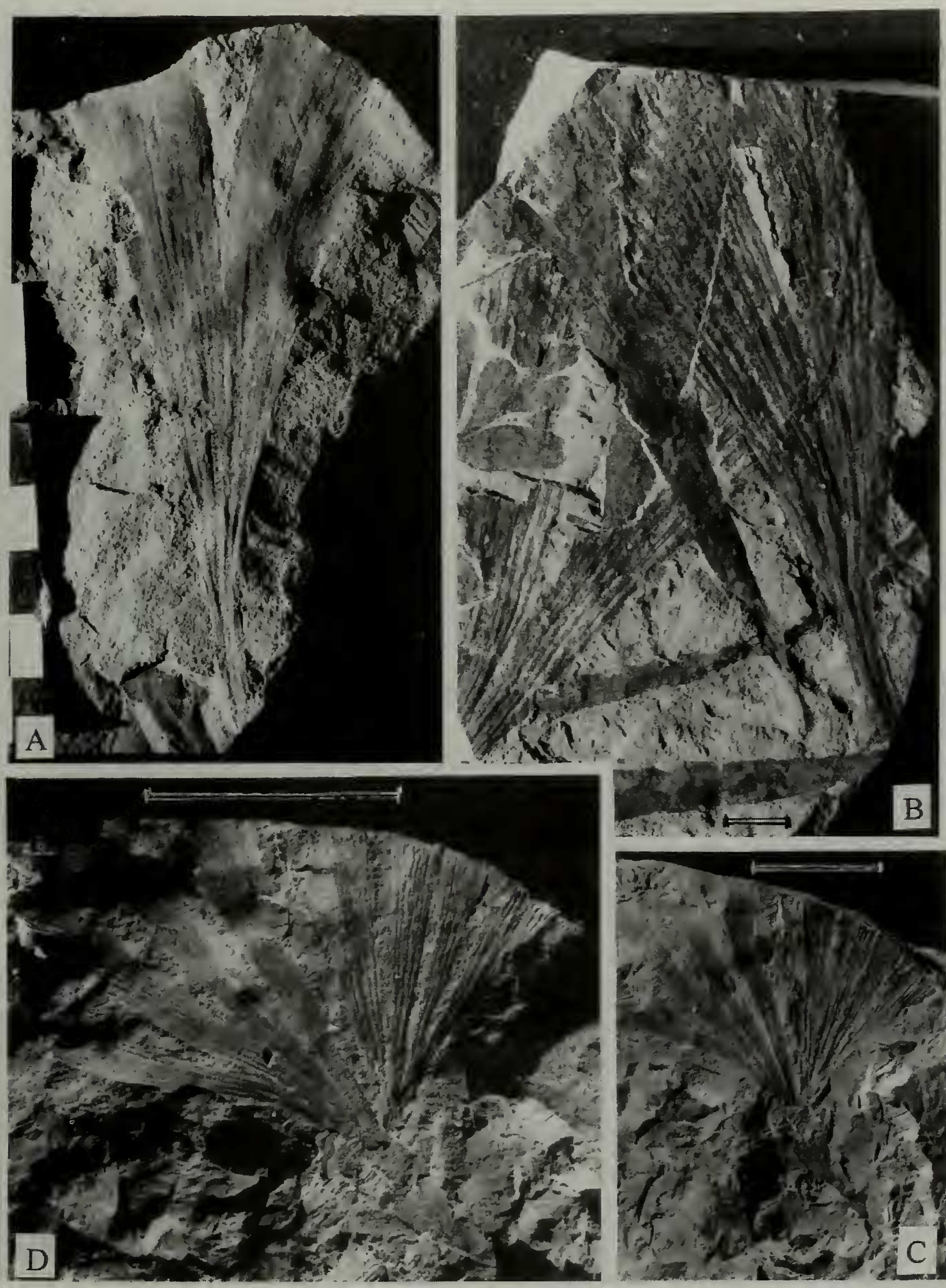

Figure 25. A,B. *Sphenobaiera sectina* Anderson and Anderson. A. AMF125101, Reserve Quarry. B. AMF125102, Coal Mine Quarry. C, D. *Sphenobaiera* sp. A. AMF125103, Coal Mine Quarry. Scale bar = 1 cm.

Figure 26. A–C. *Sphenobaiera nymbolinea* Holmes and Anderson sp. nov. A. Holotype, AMF125104; B. AMF125105, both Coal Mine Quarry. C. AMF125106, Reserve Quarry. Scale bar = 1 cm.

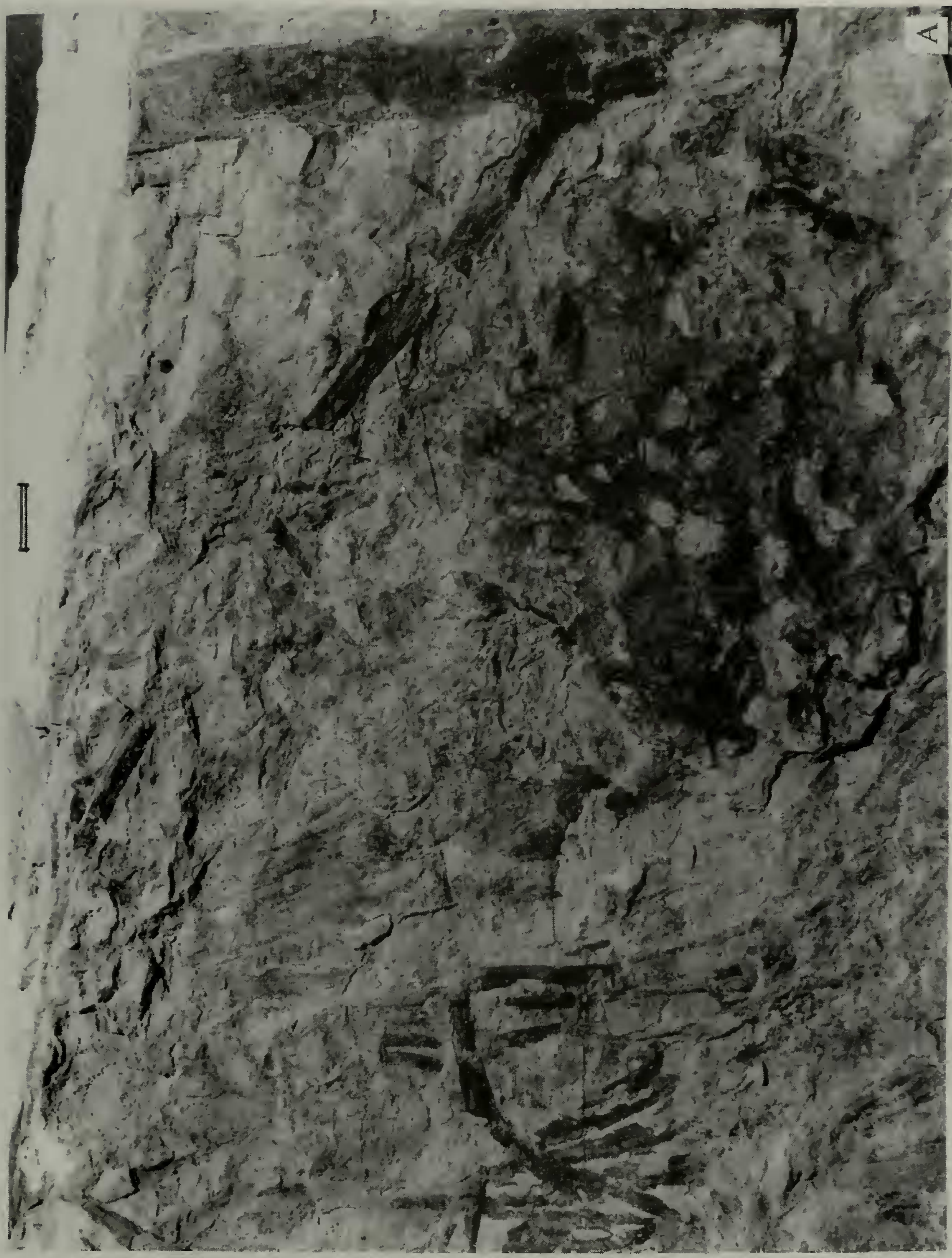

Figure 27. A. *Sphenobaiera nymbolinea* Holmes and Anderson sp. nov. Leaf assemblage. AMF125107. Reserve Quarry. Scale bar = 1 cm.

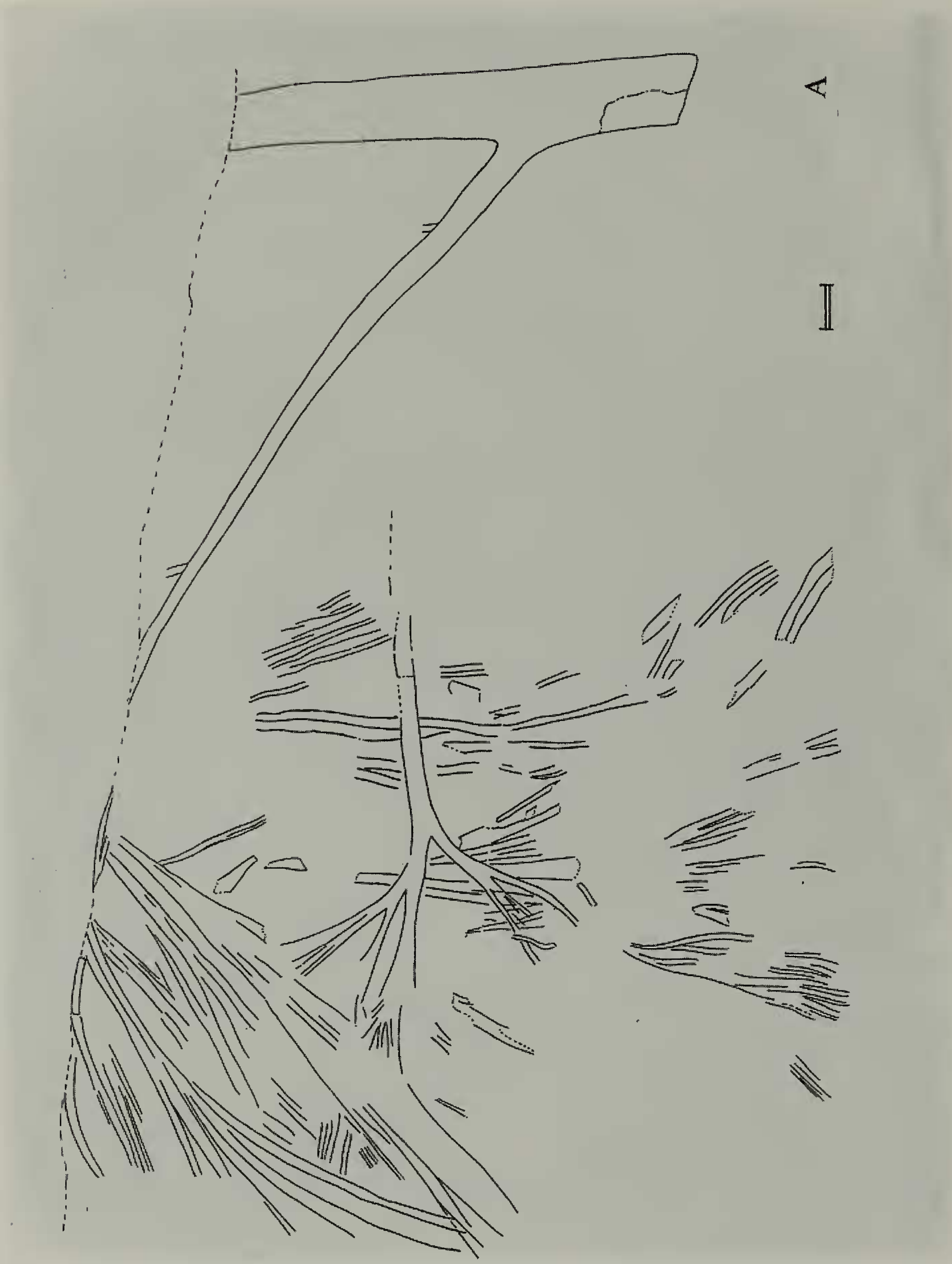

Figure 28. A. *Sphenobaiera nymbolinea* Holmes and Anderson sp. nov. Line drawing of stem and leaf assemblage based on AMF125106 and counterpart AMF125107. Scale bar = 1 cm.

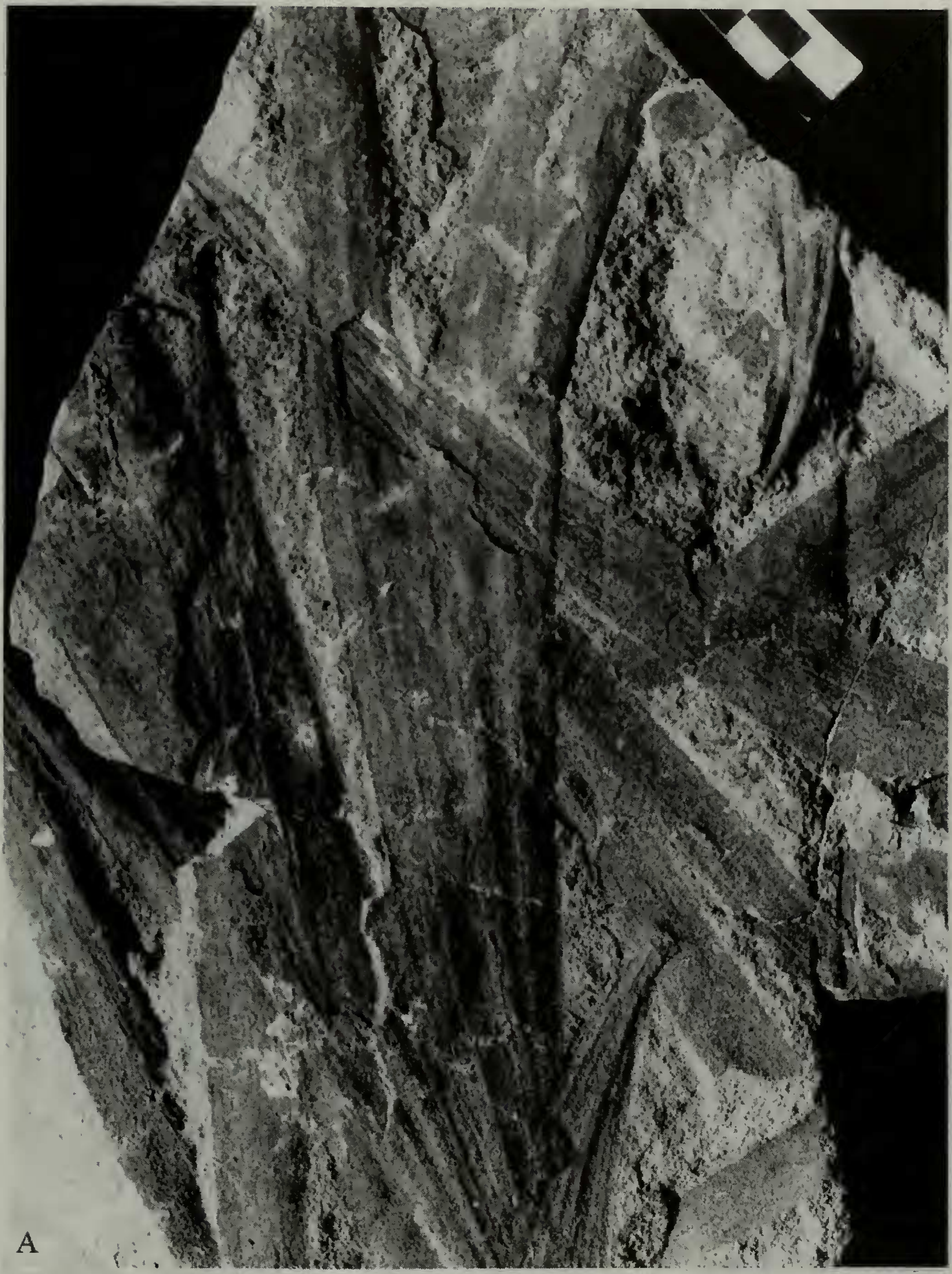

Figure 29. A. *Sphenobaiera* sp. cf. *S. browniana* Anderson and Anderson. AMF125108, Coal Mine Quarry. Scale bar = 1 cm.

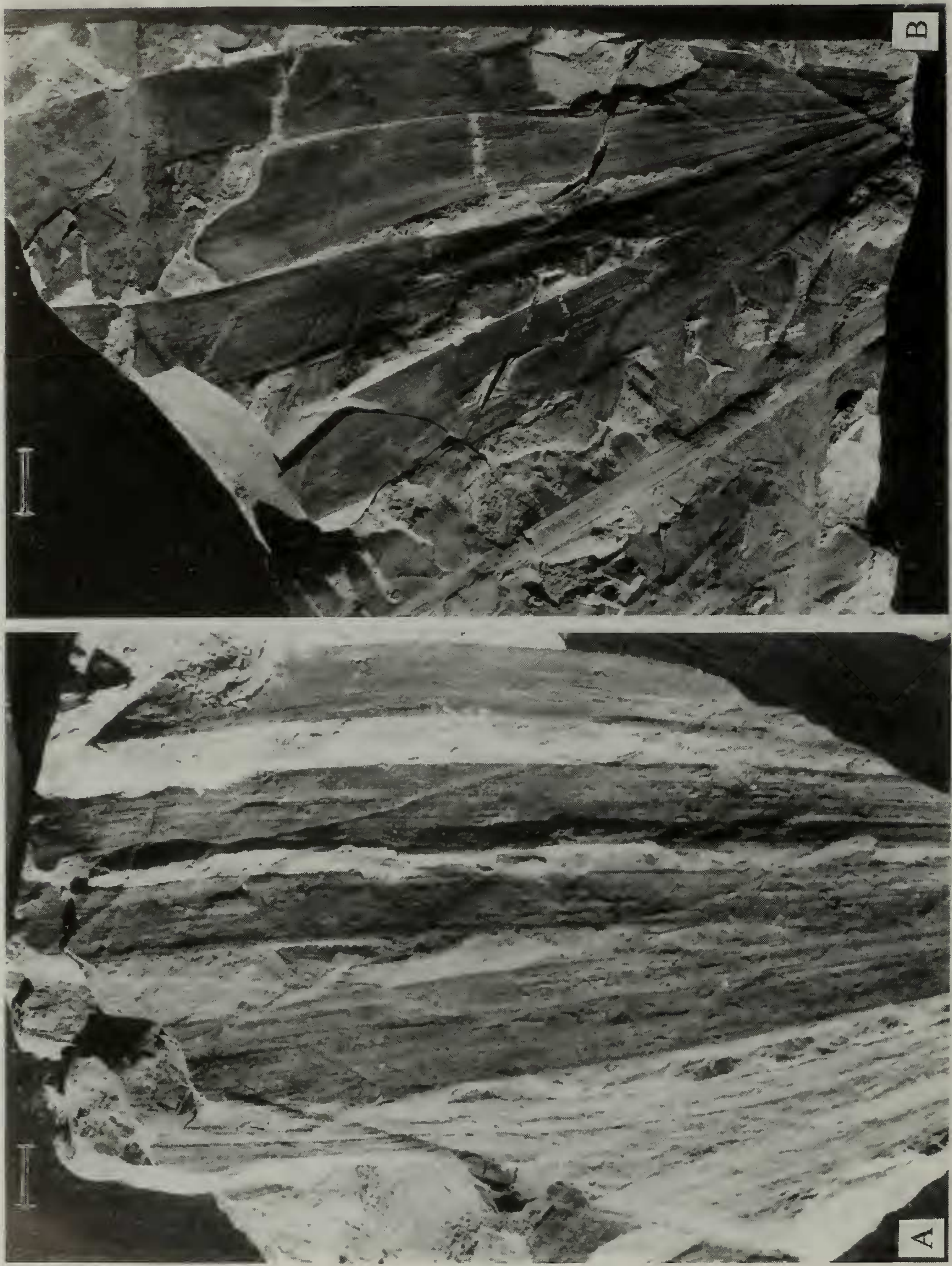

Figure 30. A,B. *Sphenobaiera* sp. cf. *S. browniana* Anderson and Anderson. A. AMF125109, Reserve Quarry. B. AMF125110, Coal Mine Quarry. Scale bar = 1 cm.

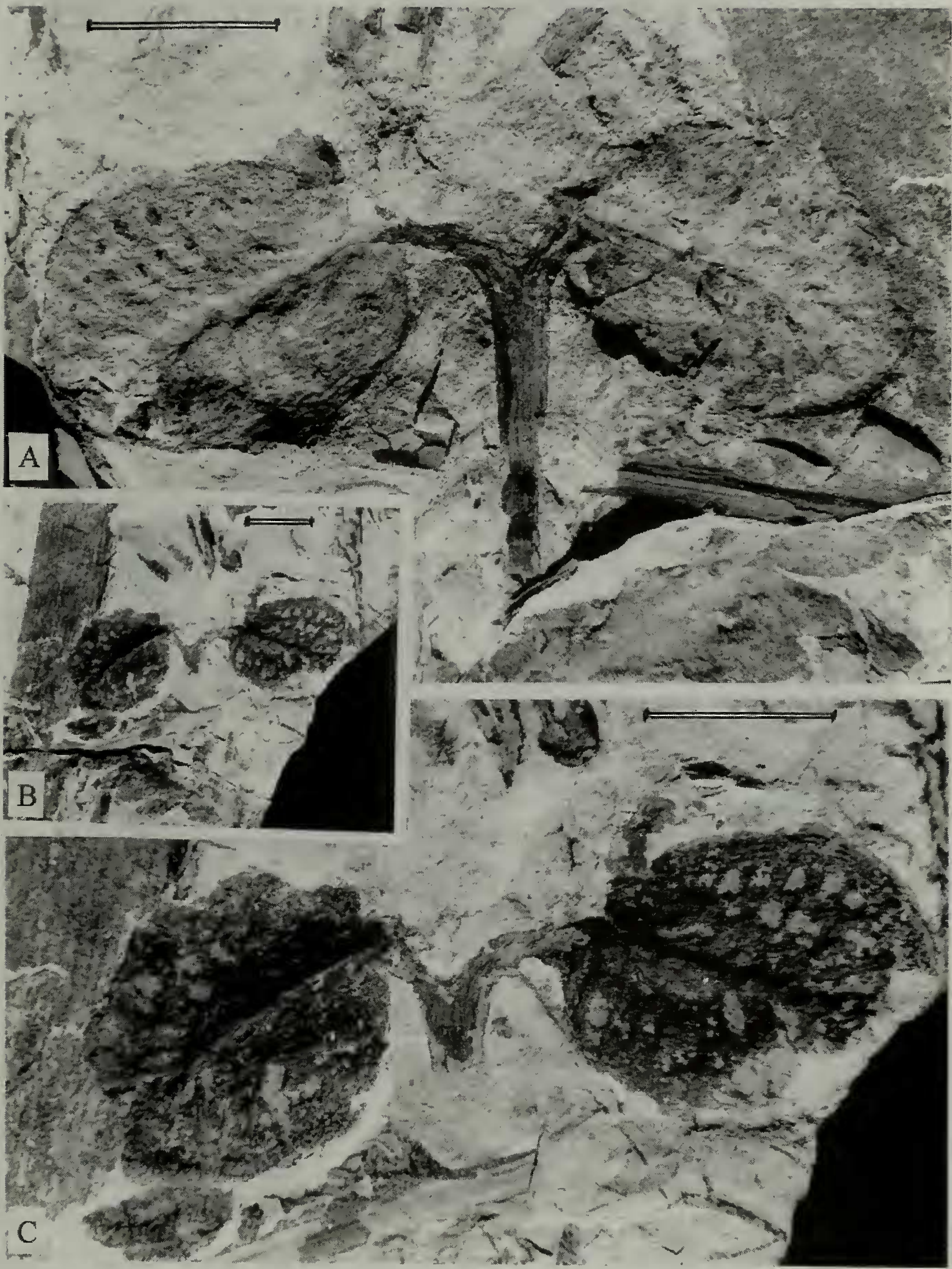

Figure 31. A–C. *Hamshawvia distichos* Holmes and Anderson sp. nov. A. Holotype, AMF129946; B,C. AMF129950, counterpart of holotype, Coal Mine Quarry. Scale bar = 1 cm.

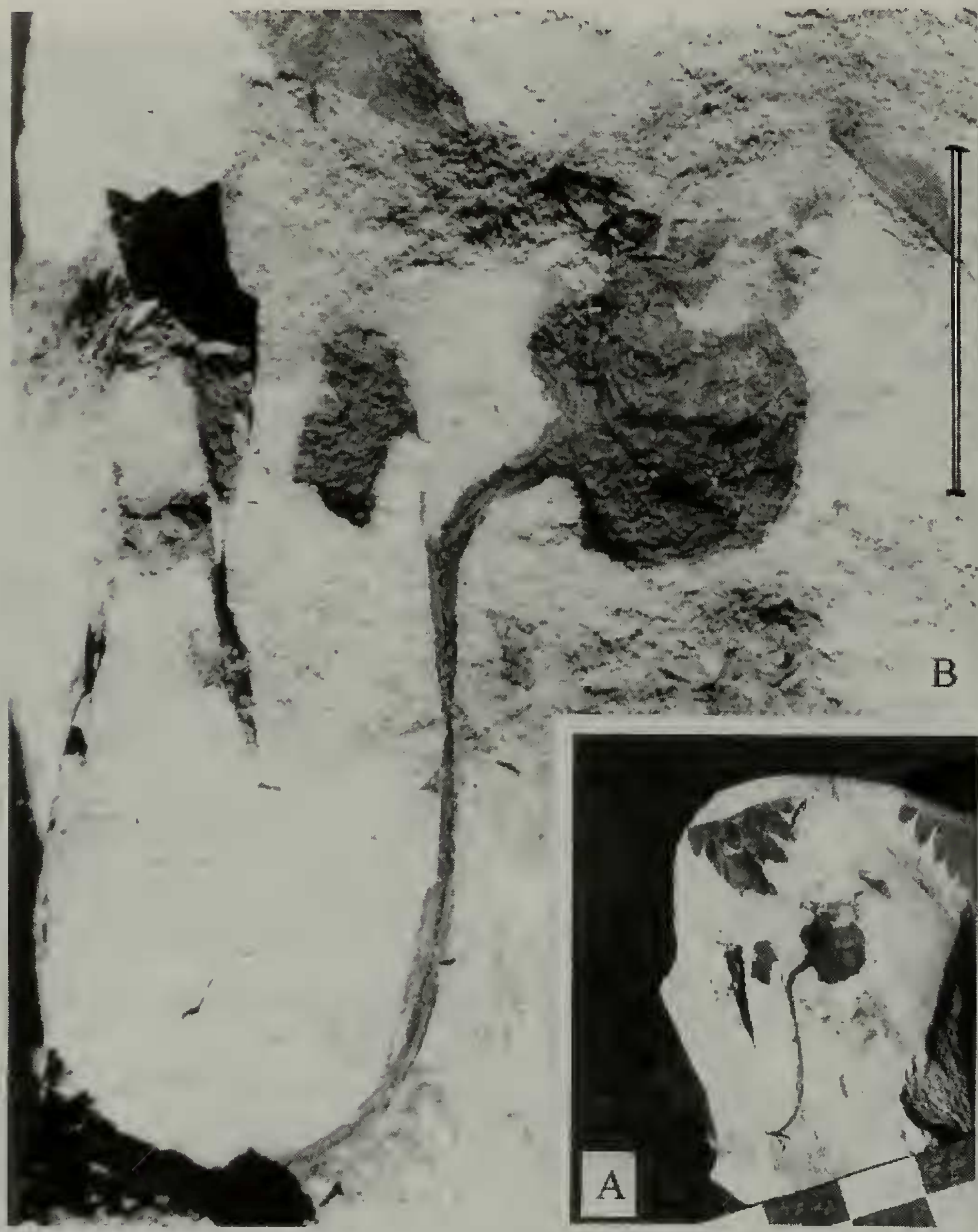

Figure 32.A,B. *Hamshawvia* sp. A. AMF125111, Coal Mine Quarry. Scale bar = 1 cm.

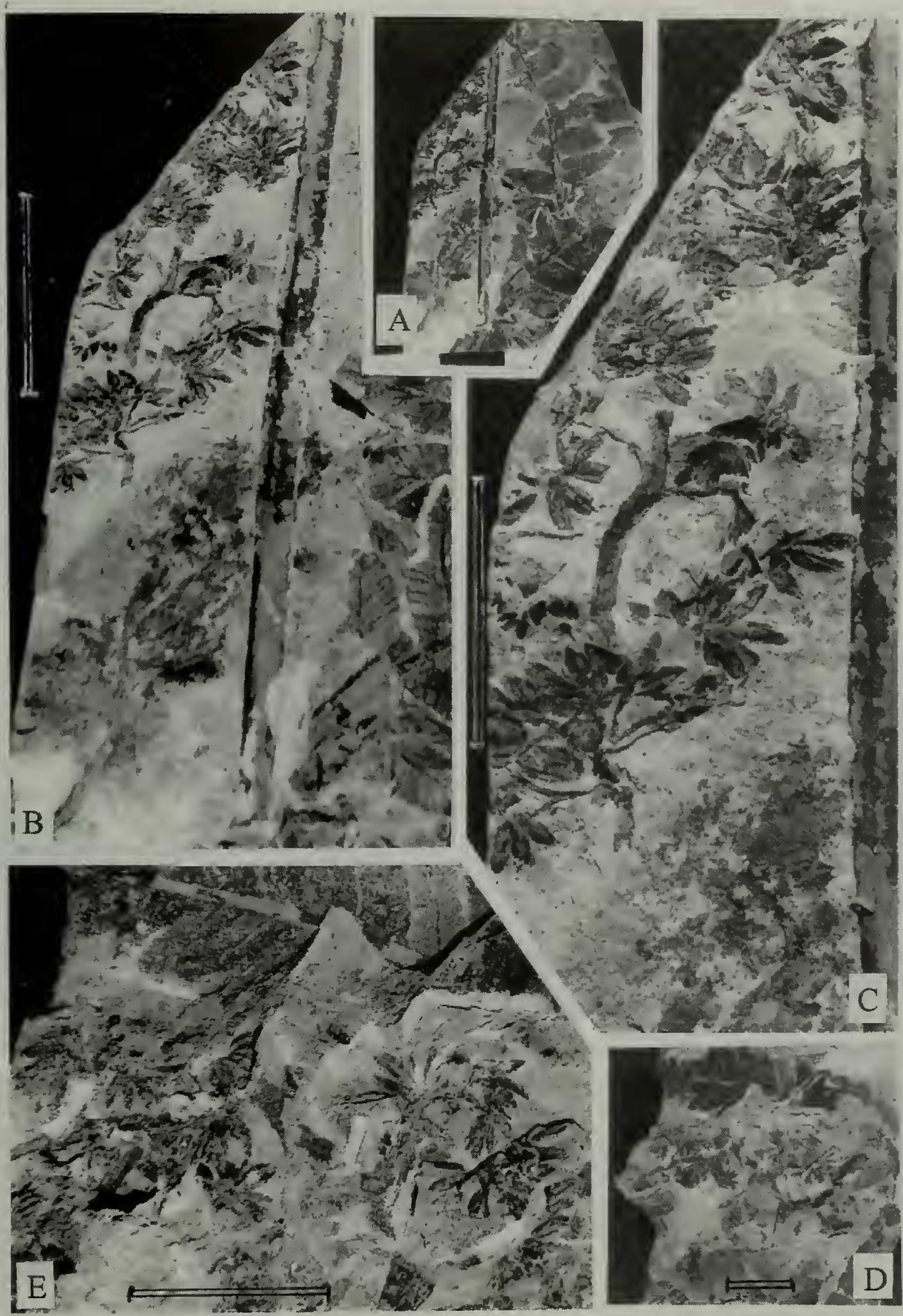

Figure 33. A–E. *Stachyopitys* sp. cf. *S. matatilongus* Anderson and Anderson. A–C. AMF125112; D,E. AMF125113. Both Coal Mine Quarry. Scale bar = 1 cm.

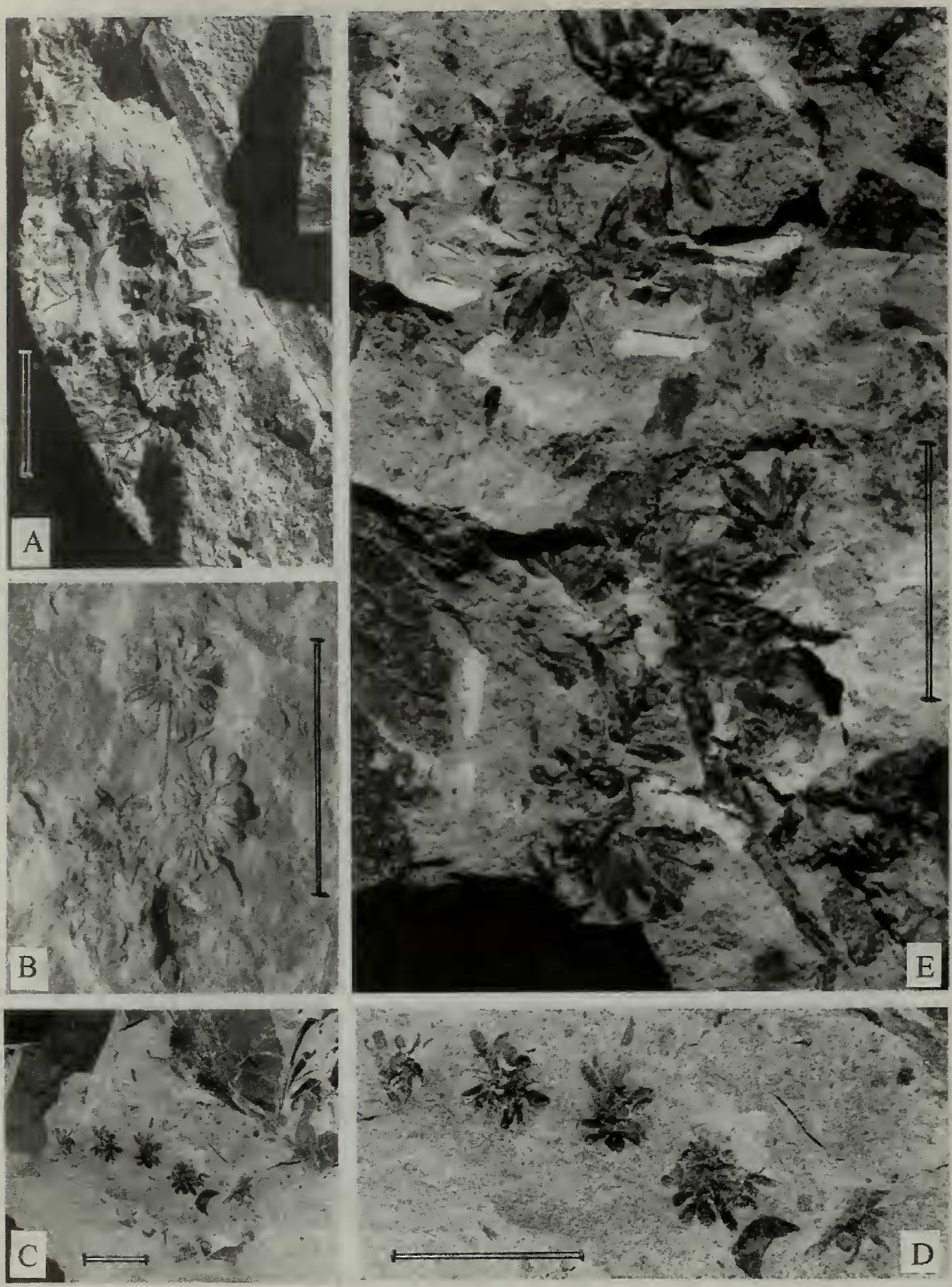

Figure 34. A,E. *Stachyopitys* sp. cf. *S. matatilongus* Anderson and Anderson. A. AMF125114; E. AMF125115; B–D. *Stachyopitys* sp. cf. *Stachyopitys lacrisporangia* Anderson and Anderson. B. AMF126855; C, D. AMF126856. All Coal Mine Quarry. Scale bar = 1 cm.